UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

ClearOne, Inc., Plaintiff, vs. Shure Incorporated, Defendant.	Civil Number 19-cv-02421 Jury Trial Demanded Hon. Edmond E. Chang
Shure Incorporated, Counter-Plaintiff, vs. ClearOne, Inc., Counter-Defendant.	

SECOND AMENDED COMPLAINT FOR PATENT INFRINGEMENT AND TRADE SECRET MISAPPROPRIATION

Plaintiff ClearOne, Inc. ("ClearOne") files this Second Amended Complaint ("SAC") against Defendant Shure Incorporated ("Shure"), and alleges as follows:

INTRODUCTION

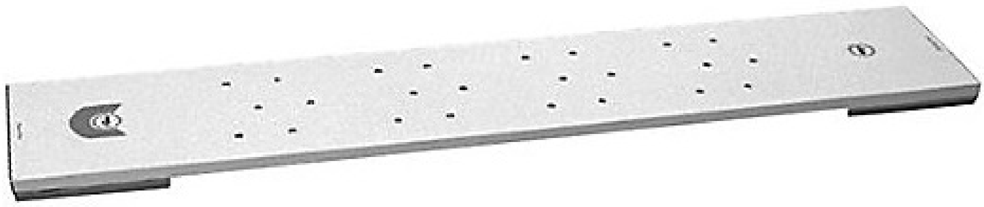
1. ClearOne brings this action to stop Shure from its predatory actions against ClearOne, including wrongful and willful infringement of ClearOne's market-leading, patented audio conferencing technologies and intentional misappropriation of ClearOne's valuable trade

secrets related to its products.[1]

2. Despite being a small public company, ClearOne had grown into the global market leader in the installed audio conferencing market and a leading provider of premium audio conferencing systems and other related products for audio, video, and web conferencing applications. As a market leader, ClearOne is focused on developing cutting-edge conferencing and collaboration products. Through decades of innovation, investment, and effort by ClearOne's inventors and engineers, ClearOne has developed industry-leading products and a portfolio of approximately 100 issued patents and pending patent applications.

3. No later than 2010, ClearOne inventors conceived and developed a beamforming microphone conferencing system that was designed to replace up to a dozen individual microphones with a compact beamforming microphone array that could be placed overhead or otherwise out of the way and yet have superior audio quality and clarity. Over the next several years, ClearOne developed this beamforming microphone conferencing system and also conceived and developed other inventions involving related technology. In 2012, ClearOne was first to market with this beamforming audio conferencing technology – the Beamforming Microphone Array ("BMA") audio conferencing system – which combined beamforming with acoustic echo cancellation and adaptive steering or smart beam selection to provide superior audio performance and clarity.

[1] Pursuant to Shure's objection to public disclosure of internal Shure documents and related material, ClearOne has redacted references to specific evidence of Shure's trade secret misappropriation from the public version of this SAC.



4. To protect its industry-leading technology, ClearOne filed provisional and utility patent applications, including United States Patent Application No. 13/493,921 (the "'921 Application") entitled "Methods and Apparatuses for Echo Cancelation with Beamforming Microphone Arrays." The '921 Application issued as United States Patent No. 9,264,553 (the "'553 Patent"). A true and correct copy of the '553 Patent is included as Exhibit A.

5. Once it was ready to sell the BMA, ClearOne encountered the issue of how to price the BMA conferencing system. Since ClearOne's beamforming microphone conferencing system was unique in the market, there was little precedent for what ClearOne should charge for the system. Accordingly, ClearOne spent significant time and effort developing highly confidential pricing lists for the BMA, including standard discounts to appeal to manufacturer representatives, dealers, resellers, and distributors, and special pricing to drive sales of this new product.

6. These highly confidential price lists carry significant value to ClearOne, and a competitor's access to these price lists would harm ClearOne's ability to compete. By maintaining the price lists confidentially, ClearOne is able to offer preferential pricing and confidential discounts. Indeed, even ClearOne partners are not permitted to share pricelists with other partners because pricing differs among different ClearOne partners. This enables ClearOne to sell more of its products and thereby positions ClearOne as the most price-effective solution. And it allows ClearOne to maintain fair pricing among various partners and partner levels. If the

price lists were made public or released to ClearOne's competitors, the competitors could simply undercut ClearOne's prices (or offer more advantageous bundle pricing) and thereby steal customers that could have otherwise bought ClearOne products. And by continually undercutting ClearOne prices, the competitors would gain goodwill and reputational benefits by appearing to be more price-competitive than ClearOne. In addition, knowing ClearOne's price lists would help the competitors better position their products in the market and save significant time in price discovery (a process where the manufacturer keeps adjusting prices to get the desired sales volume).

7. Accordingly, ClearOne maintains these lists as trade secrets, including by restricting access to them both internally and externally to only those who need to use or see them (those with a "need to know") in order to further ClearOne's business. And before sharing these highly confidential price lists with a limited number of manufacturer representatives, dealers, resellers, distributors, and employees, ClearOne marks them "Confidential" and includes strict confidentiality clauses in its contracts to protect the price lists from disclosure.

8. Due to the innovative nature of ClearOne's BMA and the BMA's significant commercial success upon entry into the market, ClearOne has been recognized several times for its continued innovation and excellence in the installed audio conferencing market.

9. Shure is a large microphone and audio company that sells products throughout the world. Witnessing the success of the ClearOne BMA in the audio conferencing market, Shure embarked on a coordinated campaign to capture market share from ClearOne. But it went about doing so in an unfair and improper manner. Within three years of the BMA's release, Shure released its own competing products: the MXA910 Ceiling Microphone Array ("MXA910") and the Microflex Advance Table Array microphone (the "MXA310"). The MXA910 and

MXA310, as designed and operated, make pervasive use of ClearOne's patented technology and infringe ClearOne's '553 Patent.

10. [redacted]

11. ClearOne files this SAC to hold Shure responsible for its deleterious conduct and prevent it from further harming ClearOne. ClearOne seeks injunctive relief barring Shure from infringing ClearOne's patented technology and from further acquiring and using ClearOne's trade secrets, damages for Shure's past infringement and trade secret misappropriation, punitive and treble damages to hold Shure responsible for its conduct, and ClearOne's attorneys' fees and costs associated with this action.

JURISDICTION AND VENUE

12. ClearOne's claim for patent infringement arises under the Patent Laws of the United States, 35 U.S.C. § 101 et seq. ClearOne's claim for trade secret misappropriation arises under the Defend Trade Secrets Act, 18 U.S.C. § 1836, et seq. Accordingly, this Court has subject matter jurisdiction over this SAC and Shure pursuant to 28 U.S.C. §§ 1331, 1338(a), 1367.

13. This Court has personal jurisdiction over Shure in this matter. Among other

things, Shure's headquarters are located at 5800 West Touhy Avenue in Niles, Illinois 60714 and it regularly transacts business in Illinois. Shure has also caused injury to ClearOne in Illinois through its willful patent infringement and trade secret misappropriation.

14. Venue is proper in this district under 28 U.S.C. §§ 1391(b) & (c) and/or 1400(b).

PARTIES

ClearOne, Inc.

15. ClearOne is a small public corporation, incorporated in Utah, with a principal place of business at 5225 Wiley Post Way, Suite 500, Salt Lake City, Utah 84116.

16. ClearOne was founded in 1983. Since its inception, ClearOne has grown to become a company dedicated to the design, development, marketing, and sales of conferencing, collaboration, and network streaming solutions for voice and visual communications. ClearOne has created hundreds of new products that improve people's ability to collaborate and communicate, whether they are in the same room or on opposite sides of the globe.

17. ClearOne's commitment to innovation and quality in the field of voice and visual communication solutions is well known. ClearOne has developed several industry firsts including, but not limited to:

- First professional-grade Beamforming Microphone Array;
- First product to use Distributed Acoustic Echo Cancellation in an audio conferencing system;
- First conference phone to provide wireless conferencing;
- First fully-scalable conference phones that daisy-chain multiple phone units;

- First product to bridge the wide price/performance gap that existed between plug-and-play tabletop conferencing phones and professionally-installed audio conferencing systems; and
- First product that is a complete professional video collaboration system with state-of-the-art audio and video technology, and a patented ceiling tile beamforming mic array designed for medium and large meeting rooms.

18. Today, installed audio conferencing is one of ClearOne's core businesses, and, before Shure's willful infringement and misappropriation, ClearOne had become the market leader in that field, with over 50% of the global market. ClearOne's products have been used by thousands of organizations worldwide, including schools, government entities, medical facilities, law firms, businesses, and houses of worship.

Shure Incorporated

19. Shure is a private corporation, incorporated in Illinois, with its principal place of business at 5800 W. Touhy Avenue, Niles, Illinois 60714.

20. Shure designs and manufactures audio systems. Shure's products include wireless and wired microphone systems, digital signal processors, and personal monitor systems, among others. Shure is a competitor of ClearOne.

21. Shure advertises, encourages, and instructs its customers to make and use integrated systems consisting of its beamforming microphones (such as the Shure MXA910 and MXA310), as well as acoustic echo cancellation products from other companies (such as QSC's Q-SYS platform and Biamp's Tesira/TesiraFORTE audio processors and software).

22. The performance of these integrated systems plays a key role in Shure's ability to compete effectively in the audio-visual conferencing market.

23. Shure is aware that ClearOne has patents relating to beamforming audio conferencing systems.

24. [redacted]

RELEVANT NONPARTIES

Biamp Systems Corporation

25. Biamp is a private corporation, incorporated in Delaware, with a principal place of business at 9300 S.W. Gemini Drive, Beaverton, Oregon 97008.

26. Biamp designs and manufactures audio and video systems. Biamp's products include networked digital audio platforms, digital signal processors, and scalable media systems for digital audio networking, among others. Biamp is a competitor of ClearOne.

27. Biamp advertises, encourages, and instructs its customers to make and use integrated systems consisting of its acoustic echo cancellation products (such as its Tesira/TesiraFORTE audio processors and software) and the Shure MXA910 and MXA310 microphones.

28. The performance of these integrated systems plays a key role in Biamp's ability to compete effectively in the audio conferencing market.

29. Biamp is aware that ClearOne has at least two patents relating to beamforming audio conferencing systems.

QSC, LLC

30. QSC is a private company organized as a California limited liability company with its principal place of business at 1675 MacArthur Blvd., Costa Mesa, California 92626.

31. QSC designs and manufacturers audio systems. QSC's products include power amplifiers, loudspeakers, audio DSP mixers, and networked audio and control. QSC is a competitor of ClearOne.

32. QSC advertises, encourages, and instructs its customers to make and use integrated systems consisting of its acoustic echo cancellation products (such as its Q-SYS platform) and the Shure MXA910 and MXA310 microphones.

33. The performance of these integrated systems plays a key role in QSC's ability to compete effectively in the audio conferencing market.

34. QSC is aware that ClearOne has at least two patents relating to beamforming audio conferencing systems.

BACKGROUND OF THE TECHNOLOGY

35. The technology at issue in this case pertains generally to the field of digital signal processing techniques, as used primarily in audio and video teleconferencing systems that are often deployed in conference rooms.

36. Beamforming, also known as spatial filtering, is a signal processing technique used in sensor arrays for directional signal transmission or reception. Beamforming can be used to select desired sound sources, while rejecting unwanted sounds. In an audio conferencing system, beamforming can be used to select, or focus on, a participant's voice, while rejecting noise and interfering speech, in order to provide superior audio performance and clarity.

37. Another related and important technology in audio conferencing is acoustic echo cancellation. Acoustic echo cancellation involves recognizing an echo, and then reducing or removing it by subtracting it from a transmitted signal. For example, during an audio conference, the voice of a speaker on one end of a conference line is output through speakers at

the other end of the conference line. Often, that speaker output is then picked up by the microphones on the same end of the conference line, and relayed back to the original speaker as undesirable echo. Acoustic echo cancellation reduces, eliminates, or minimizes this effect.

38. ClearOne was at the forefront of integrating beamforming microphone arrays with acoustic echo cancellation. ClearOne's '553 Patent covers methods and apparatuses that, among other things: (1) perform a beamforming operation that combines a plurality of microphone signals into a smaller number of combined signals that each correspond to a different fixed beam; and (2) performs an acoustic echo cancellation operation on the combined signals.

39. The '553 Patent employs a particular "hybrid" method, wherein microphone signals are beamformed into a plurality of fixed beams, and echo cancellation is then applied to those fixed beams. Performing the echo cancellation step on pre-formed, fixed beams minimizes the computer processing effort involved in acoustic echo cancellation, while also keeping the absolute number of echo cancellers to a minimum. This solves two problems that plagued other methods at the time of invention of the '553 Patent.

40. Ashutosh Pandey, Darrin Thurston, David Lambert, and Tracy Bathurst, the inventors of the '553 Patent, created the methods recited therein after unsuccessful attempts to develop other beamforming and echo cancellation technologies. For example, Mr. Pandey and his team members worked for over a year on a project that performed acoustic echo cancellation first, and then conducted beamforming using the output of each microphone signal. This project was ultimately scrapped due to high costs, high processing requirements, and insufficient sound quality.

41. Pandey and his co-inventors then went back to the drawing board and began developing a beamforming microphone array that would use fixed beams. Ultimately, they

realized that they could dramatically reduce processing requirements and achieve excellent sound quality by *first* using a digital signal processor ("DSP") to perform a beamforming algorithm and *then* performing AEC on the signals of each fixed beams, rather than performing AEC on the output of each microphone. The result was a new technology with significant cost and processing improvements and excellent sound quality. It is this new technology that is described and claimed in the '553 Patent.

42. ClearOne currently employs the technology in the '553 Patent in its Beamforming Microphone Array and CONVERGE Pro products, both of which are now in their second generation. ClearOne also employs the technology in its BMA CT ceiling tile beamforming microphone array, ClearOne's third-generation product.

SHURE'S INFRINGEMENT OF CLEARONE'S '553 PATENT

43. In or around January 2016, Shure announced the release of its MXA910 (Ceiling Array) and MXA310 (Table Array) microphones. The microphones began shipping later that year, in August 2016. Shure continues to sell both microphone products today.

44. The Shure MXA910 and MXA310 microphones utilize the technology in the '553 Patent. Both Shure microphone products offer the same beamforming as that claimed in the '553 Patent. Specifically, they, among other things: perform a beamforming operation with a beamforming module; combine "[m]ultiple mic elements together to produce multiple, highly-directional pickup lobes"; and combine a plurality of microphone signals such that each of the plurality of combined signals corresponds to a different fixed beam.

45. Shure's MXA910 and MXA310 microphones also require acoustic echo cancellation ("AEC"). To provide this functionality, Shure directs end users to use digital signal processors with Shure's MXA910 and MXA310 microphones. At first, Shure encouraged the

use of QSC's Q-SYS platform and Biamp's Tesira/TesiraFORTE audio processors and software—both of which provide the required AEC—with their MXA910 and MXA310 microphones. Now, Shure also offers its own digital signal processor, the Shure IntelliMix P300.

46. Combined with a DSP, the Shure MXA910 and MXA310 microphones offer the same combination of beamforming and acoustic echo cancellation as ClearOne's BMA. In fact, upon its release of the MXA910 and MXA310, Shure become the only company in the United States to sell a substantially similar beamforming microphone array to ClearOne's BMA. Shure's infringement, on its own and in combination with others, has harmed ClearOne's investments in technology and its reputation as a leader and innovator.

SHURE'S KNOWLEDGE AND WILLFUL PATENT INFRINGEMENT

47. Shure has knowingly infringed and willingly continued to infringe the '553 Patent by selling its MXA910 and MXA310 products, even after challenging ClearOne's '553 Patent in federal court and unsuccessfully with the PTAB.

48. On April 24, 2017, Shure filed an action in the U.S. District Court for the Northern District of Illinois seeking a declaratory judgment of noninfringement and invalidity of the '553 Patent. *Shure Inc. v. ClearOne, Inc.*, Case No. 17-cv-03078 (N.D. Ill.).

49. ClearOne had filed an application for reissue of the '553 Patent on April 16, 2017, prior to Shure's SAC. On July 14, 2017, Shure filed a petition for *Inter Partes* Review ("IPR") of the '553 Patent, and on January 29, 2018, the Patent Trial and Appeal Board ("PTAB") instituted IPR proceedings for the '553 Patent.

50. On March 16, 2018, the Court declined to exercise jurisdiction over Shure's declaratory judgment claim with respect to the '553 Patent, noting that "[t]he '553 patent is currently in reissuance proceedings before the Patent and Trademark Office, and the Patent Trial

and Appeal Board recently granted *inter partes* review of the patent." (*See Shure Inc. v. ClearOne, Inc*., Case No. 17-cv-03078 at Dkt. 280.)

51. On January 24, 2019, the PTAB issued its unanimous Final Written Decision for the IPR of the '553 Patent, finding that Shure "ha[d] not demonstrated by a preponderance of the evidence that any of [the challenged claims] are unpatentable under 35 U.S.C. §§ 103(a)." (*See* Case No. 17-cv-03078 at Dkt. 478, Ex. A.) The PTAB panel which reached this decision consisted of three technically trained administrative patent judges: Dr. Kevin Turner (Ph.D., Physics), Joni Chang (B.Sc., Chemical Engineering), and Arthur Peslak (M.Sc., Mechanical Engineering). According to a 2017 publication, Judges Chang and Turner are two of the PTAB's most experienced patent judges; both Judge Chang and Judge Turner have presided over more than 400 PTAB trials.

52. Shure filed a Request for Rehearing ("Request") of the PTAB's Final Written Decision on February 22, 2019. Just over a month later, on March 25, 2019, the PTAB denied Shure's Request, holding, among other things, that Shure's contentions were "without merit," "not persuasive," and "unavailing." Under the law—including 35 U.S.C. § 325(e)(2)—Shure should be estopped from asserting invalidity of the '553 Patent "on any ground that [it] raised or reasonably could have raised during th[e] post-grant review."

SHURE'S MISAPPROPRIATION OF CLEARONE TRADE SECRETS

53. In the audio conferencing market, two of the principal factors that market participants, including manufacturer representatives, dealers, resellers, and distributors, take into account when choosing a conferencing product are technology and pricing. As discussed above, the BMA became successful in large part due to its unique technology—yielding improved performance—and the functionalities it could offer because of that technology. But another

important driver of success for the BMA—along with ClearOne's other products—was pricing.

54. Before the BMA was first released, ClearOne spent considerable time deliberating about what the right price should be for a product with such unique technology and resultant performance. It was an arduous task, because there was no directly competitive product that it could be compared to. Accordingly, ClearOne developed pricing for the BMA by examining, among other things, the benefits the BMA offered above and beyond benefits offered by existing products at the time, costs of procuring and installing existing products, and costs of manufacturing the BMA. ClearOne then worked into its pricing tiered discounts for its manufacturer representatives, dealers, resellers, and distributors based on purchasing volume and other factors. ClearOne developed this pricing to gain a competitive advantage over other products in the market.

55. Price lists are a "secret sauce" in the audio-visual conferencing industry. The publicly-available MSRP prices for conferencing products have only indicative value, as bids for projects are rarely won based on MSRP prices. Instead, dealers, integrators, and use resellers win bids by offering confidential discounts and preferential pricing. Industry participants thus take significant measures and time to develop their price lists, and to ensure that they are not being released to their competitors.

56. ClearOne memorialized its prices for the BMA and its other products in highly confidential distributor and dealer price lists, specific to each region that it operated in. In the United States, ClearOne called these price lists "North America Pricing Guides." Price lists in the United States were offered under different tiers, namely Distributor, Platinum Dealer, Gold Dealer and Dealer. ClearOne shared these price lists with its manufacturer representatives, dealers, resellers, and distributors to ensure that they had up-to-date pricing—applicable to

particular distributors or dealers based on the tier to which they belonged—when deciding between ClearOne and other products for end users. And ClearOne ensured that the dealers, resellers, and distributors got access to only the price list applicable to them based on whether they were a Distributor, a Platinum Dealer, a Gold Dealer, or a Dealer.

57. Although ClearOne had to share its highly confidential price lists to carry out its business, ClearOne took numerous steps to keep the price lists confidential, and especially to keep the price lists out of the hands of ClearOne's competitors. It was—and is—important for ClearOne to keep the price lists secret because the price lists provide ClearOne a competitive advantage in selling its products. ClearOne strategically uses the price lists to offer confidential discounts and preferential pricing to be competitive and win projects. ClearOne has a clear advantage in the market when it can provide the best conferencing product at the best prices. However, if the price lists were disclosed publicly, competitors—like Shure—could use the knowledge of ClearOne's confidential discounts and preferential pricing to undercut ClearOne's prices. The competitors would then be positioned as the more price-efficient conferencing option and would gain goodwill from manufacturer representatives, dealers, resellers, distributors, and end users at the expense of ClearOne. In addition, even if competitors who got access to ClearOne's highly confidential price lists did not use those lists to undercut ClearOne's prices, they could use their knowledge of ClearOne's prices to, among other things, protect their price from getting too low and save time by not bidding for projects that they know, based on ClearOne's prices, would not let them obtain the required margins. Moreover, competitors could quote a slightly lower price than they would otherwise—even if higher than ClearOne's—and then attempt to justify their only-slightly-increased price to purchasers.

58. ClearOne's efforts to maintain the confidentiality of the price lists started with

marking every page of the price lists with a "ClearOne Confidential" stamp to make it clear to any reader that the price lists were (and contained) ClearOne's confidential information.

59. Internally, ClearOne locks down and secures access to the highly confidential price lists. IT restricts access to the price lists to only those ClearOne employees who have a need to access and view the price lists—*e.g.*, an engineer does not have access to the price lists. If an employee without access wants to obtain access to the price lists, the employee needs to get authorization from his/her manager and then also obtain authorization from the ClearOne Sr. Vice President of Finance. Once granted access, the employee only has access to the specific price lists they require, not every ClearOne price list. For example, sales persons only have access to the price lists applicable to their regions. These strict requirements are part of ClearOne's internal IT controls that are key to its public reporting and in compliance with the requirements of the Sarbanes-Oxley Act of 2002. These practices and policies have been in place at all times relevant to this lawsuit.

60. Moreover, ClearOne employees are, as a condition of their employment, required to execute a non-disclosure agreement in which they agree, among other things, not to improperly use and/or disclose ClearOne confidential information and trade secrets during or after the course of their employment at ClearOne. ClearOne employees are reminded of their covenants of confidentiality throughout their employment, including in the Employee Handbook, which they need to periodically sign to acknowledge receipt and understanding. Employees' confidentiality obligations pursuant to these signed agreements apply throughout their employment and beyond termination.

61. Similar restrictions apply to external recipients, including sales channel partners such as manufacturer representatives, dealers, resellers, and distributors. Before sending any

highly confidential price lists, ClearOne requires external recipients to sign agreements with broad confidentiality clauses that prohibit them from disclosing this confidential information to anyone outside of ClearOne's sales channel or to anyone without a need to know. For example, one such confidentiality clause states:

> "Reseller understands and acknowledges that in order to facilitate the business arrangements contemplated by this Agreement, certain confidential and proprietary technical, financial and/or business information of ClearOne will be disclosed to Reseller. This confidential and proprietary information includes, without limitation, all proprietary inventions, sales support materials, processes, product design(s), drawing and schematics of product design(s), methods of doing business, pricing, marketing programs, and other data and information, whether patented or not, heretofore or hereafter developed or acquired by ClearOne in the course of the design, manufacture, marketing, or sale of or otherwise relating to the Products or future conceptual or unreleased products. Reseller acknowledges that all ClearOne Confidential Information is the exclusive property and trade secrets of ClearOne. Reseller agrees not to use or disclose any ClearOne Confidential Information in any manner adverse to the best interests of ClearOne."

Finally, ClearOne only sends external partners the specific price list applicable to them, which depends on their region and purchasing tier. For example, a dealer in Illinois in March 2016 would only receive the North American Dealer price list for March 2016 that relates to that dealer's partner level, not the price lists for any other region, any other period, or any other partner level. ClearOne transmits the highly confidential price lists via e-mail to external partners in e-mails that state that the "electronic mail message and any attachment is confidential."

62. [redacted]

63. [redacted]

64. [redacted]

65. [redacted]

[redacted]

66. [redacted]

67. [redacted]

68. Shure's brazen and illegal conduct has yielded it considerable benefit. [redacted]

[redacted]

69. The effects on ClearOne are also clear: among other things, lost sales and loss of goodwill due to Shure's anticompetitive behavior.

COUNT I

Claim for Relief for Patent Infringement of the '553 Patent

70. ClearOne incorporates by reference paragraphs 1 through 69 and Exhibits A-G attached hereto.

71. ClearOne is the owner of all rights, title, and interest in the '553 Patent. The '553 Patent issued on February 16, 2016.

72. The '553 Patent is valid and enforceable. Indeed, under the law—including 35 U.S.C. § 325(e)(2)—Shure should be estopped from asserting invalidity "on any ground that [it] raised or reasonably could have raised" during the IPR Shure lost while attempting to challenge the validity of the '553 Patent.

73. Defendant Shure manufactures, uses, offers to sell, and sells beamforming microphone arrays and digital signal processing platforms and thereby directly infringes at least one claim of the '553 Patent. Shure advertises, encourages, and instructs its customers to make, use, offer to sell, and/or sell infringing integrated systems consisting of Shure's beamforming microphones (such as the MXA910 and MXA310) and digital signal processors that perform acoustic echo cancellation (such as Shure's IntelliMix P300, QSC's Q-SYS platform, and Biamp's Tesira/TesiraFORTE audio processors and software). Upon information and belief, the

Shure beamforming microphones practice a material part of the claimed invention of the ’553 Patent, have no substantial non-infringing use, and are marketed and sold to be used together with a digital signal processor that performs acoustic echo cancellation.

74. Shure’s beamforming microphones are intended for audio and video conferencing. *See, e.g.,* Exhibit H (Shure MXA310 User Guide Excerpt) at 1 (“The Microflex® Advance™ table array is a premium networked tabletop microphone for AV conferencing environments, including boardrooms, huddle rooms, and multi-purpose spaces.”); Exhibit I (Shure MXA910 User Guide Excerpt) at 1 (“The Microflex® Advance™ Ceiling Array is a premium networked array microphone for AV conferencing environments, including boardrooms, huddle rooms, and multi-purpose spaces.”). Upon information and belief, for audio conferencing purposes, the Shure MXA910 and MXA310 beamforming microphones require acoustic echo cancellation (“AEC”). The AEC functionality is provided to the MXA910 by digital signal processors such as by Shure’s IntelliMix P300, QSC’s Q-SYS platform, and Biamp’s Tesira/TesiraFORTE audio processors and software. These integrated systems thus infringe the ’553 patent, including by performing beamforming operations that combine microphone signals into signals corresponding to fixed beams, and then perform acoustic echo cancellation on the combined signals.

75. In addition, Shure has formed joint enterprises with several AV hardware and software providers, including both Biamp and QSC, to manufacture and sell these infringing integrated systems to customers. *See, e.g.*, Exhibit J (2017-02-07 Press Release) (“Shure Expands Partnership Program With Leading AV Hardware and Software Providers … [including] Biamp, QSC ….”); Exhibit K (QSC-Shure Software Integration Alliance (accessed Apr. 9, 2019)) (“Shure and QSC have co-developed a control plugin for their Microflex Wireless

microphone series." In addition, specific microphones in the Shure catalog, including the Microflex Wireless series, can pass audio to the Q-SYS Platform via AES67, all without additional Dante I/O card hardware."); Exhibit L (2017-01-09 Press Release) ("QSC, LLC and Shure Incorporated are proud to announce an expanded level of integration between Shure Microflex® Advance™ and Microflex® Wireless microphones with the entire Q-SYS™ Platform. The partnership includes the release of new control plug-ins for the Shure MXA910 Ceiling Array Microphone and Microflex Wireless microphone systems."); Exhibit M (2016-12-06 Press Release) (Biamp is "excited to come together with an industry leader like Shure in an effort to streamline the integration of [their] products"; "Adding Shure microphone-specific software blocks to [Biamp] Tesira's cutting-edge software made sense; it allows system designers to easily incorporate the power of Shure mics with the power of [Biamp] Tesira."); Exhibit N (2018-10-02 Biamp Article) ("The purpose of this article is to provide a starting point to aid in the successful deployment of the [Biamp] TesiraFORTÉ DAN with Shure MXA910 and/or MXA310 microphone arrays."); Exhibit O (Shure Q&A) (answering that customers can use QSC Qsys with MXA310). Shure thereby jointly infringes one or more claims of the '553 Patent, including claims 1, 8, and 15 of the '553 Patent, by conditioning the receipt of a benefit to the end user on performing the steps outlined in the '553 Patent. And Shure uses, offers to sell and/or sells in the United States, and/or imports into United States, the infringing integrated systems.

76. Shure has also induced and continues to induce infringement of one or more claims of the '553 Patent, including, without limitation, claims 1, 8, and 15 of the '553 Patent, by supplying, advertising and/or providing instructions for the infringing integrated systems with the specific intent that its customers infringe the '553 Patent despite knowledge that its

customers' induced acts infringe the '553 Patent. Shure has also contributorily infringed and continues to contributorily infringe one or more claims of the '553 Patent, including, without limitation, claims 1, 8, and 15 of the '553 Patent, by, despite its knowledge of the '553 Patent, offering to sell and selling within the United States, or importing into the United States, material components of the claimed invention in the '553 Patent that have no substantial non-infringing use to Shure's customers, knowing such components are especially made or adapted for use to infringe the '553 Patent.

77. In addition, upon information and belief, Shure has supplied and continues to supply—from the United States to foreign countries—the individual components (including hardware, software, and firmware) of the MXA910, MXA310, and IntelliMix P300 which constitute all or a substantial portion of the components of the apparatus claimed in the '553 Patent. Shure is inducing the combination of these individual components—into the apparatus claimed in the '553 Patent—outside of the United States in at least Shure's Juarez, Mexico manufacturing plant.

78. Upon information and belief, Shure has also supplied and continues to supply—from the United States to foreign countries including but not limited to China, Brazil, and Germany—the completed MXA910, MXA310, and IntelliMix P300, which individually constitute a substantial portion of the components of the '553 Patent. Shure is inducing its customers into combining the MXA910 and MXA310 with the P300, Tesira/TesiraFORTE, or Q-SYS audio DSP mixers outside of the United States.

79. Shure is intending and inducing each of the aforementioned combinations despite its knowledge that these combinations would infringe the '553 Patent if they occurred in the United States.

80. In addition, upon information and belief, Shure has supplied and continues to supply—from the United States to foreign countries including but not limited to China, Brazil, and Germany—the MXA910 and MXA310 microphones, despite knowing that it is not a staple article suitable for substantial noninfringing use, but is especially made or adapted for use in an infringing combination with the P300, Tesira/TesiraFORTE, or Q-SYS. Shure is intending that the MXA910 and MXA310 be combined with the P300, Tesira/TesiraFORTE, or Q-SYS.

81. Shure is intending and inducing each of the aforementioned combinations despite its knowledge that these combinations would infringe the '553 Patent if they occurred in the United States.

82. Shure knew of the '921 Application, including after its issuance as the '553 Patent. Indeed, Shure filed litigation against ClearOne relating to the '553 Patent.

83. Shure's infringement is willful.

84. ClearOne has suffered and continues to suffer damages and irreparable harm because of Shure's past and ongoing infringement.

85. Unless Shure's infringement is enjoined, ClearOne will continue to be damaged and irreparably harmed. ClearOne meets the criteria for, and is entitled to, temporary, preliminary, and permanent injunctive relief.

COUNT II

Claim for Misappropriation of Trade Secrets Under the Defend Trade Secrets Act (18 U.S.C. § 1836, et seq.)

86. ClearOne incorporates by reference paragraphs 1 through 85 and Exhibits A-O attached hereto.

87. ClearOne's highly confidential price lists constitute protectable trade secrets under the federal Defend Trade Secrets Act, codified at 18 U.S.C. § 1836 et seq. ("DTSA").

ClearOne's successful business is directly dependent upon maintaining the secrecy of its trade secrets and other confidential and proprietary information. ClearOne's nonpublic price lists for its products are business and economic information. The price lists derive independent economic value from being nonpublic because they provide ClearOne a competitive advantage in being able to offer preferable pricing to sell its products. If the price lists were publicly available, ClearOne's competitors would be able to use the price lists to, among other things, undercut ClearOne and win sales and harm ClearOne's ability to maintain fair and orderly pricing among its channel partners.

88. ClearOne's highly confidential price lists are meant to be used to sell ClearOne's products throughout the United States and worldwide. Accordingly, ClearOne's trade secrets at issue are related to a product or service used in, or intended for use in, interstate commerce.

89. ClearOne takes reasonable measures to keep its highly confidential price lists confidential. For example, it includes broad confidentiality provisions in its contracts with manufacturer representatives, dealers, resellers, and distributors to ensure that they do not share the price lists outside of the ClearOne sales channel. Moreover, ClearOne routinely marks the dealer price lists "Confidential" to make it clear that the price lists are not meant to be shared outside of those with a need to know. ClearOne also restricts the dissemination of price lists both internally at ClearOne and externally to manufacturer representatives, dealers, resellers, and distributors. Only employees with express authorization of the Sr. Vice President of Finance and their manager are authorized access to the price lists and, even then, only the specific price lists they require. With respect to external persons, only those specific price lists are shared that will assist the manufacturer representatives, dealers, resellers, and distributors in selling ClearOne products and the e-mail transmittal of the price lists contains language making clear to the

recipient that the communication and attachment are confidential.

90. [redacted]

91. [redacted]

92. [redacted] Shure's conduct caused ClearOne to lose sales that it would have otherwise not lost, if not for Shure's misappropriation.

93. As a proximate result of Shure's misappropriation, ClearOne has suffered, and will continue to suffer, actual damages, and Shure will be unjustly enriched, in sums not yet

ascertained. ClearOne has also suffered and will continue to suffer immediate and irreparable harm, and will continue to suffer such injury until the breaches are preliminarily and permanently enjoined.

94. Shure's misappropriation was intentional, malicious, and in bad faith. It has subjected and will continue to subject ClearOne to unjust hardship in conscious disregard of ClearOne's rights, so as to justify an award of exemplary and punitive damages according to proof at trial. Under the DTSA, ClearOne is entitled to recover its reasonable attorneys' fees as a result of Shure's willful and malicious misappropriation.

COUNT III

Claim for Misappropriation of Trade Secrets Under the Illinois Trade Secrets Act (765 ILCS 1065) (Against Shure)

95. ClearOne incorporates by reference paragraphs 1 through 94 and Exhibits A to O attached hereto.

96. ClearOne's highly confidential price lists constitute protectable trade secrets, as defined in the Illinois Trade Secrets Act ("ITSA") at 765 ILCS 1065/2(d). ClearOne's successful business is directly dependent upon maintaining the secrecy of its trade secrets and other confidential and proprietary information. ClearOne's nonpublic dealer price lists for its products are business and economic information. The price lists derive independent economic value from being nonpublic because they provide ClearOne a competitive advantage in being able to offer preferable pricing to sell its products. If the price lists were publicly available, ClearOne's competitors would be able to use the price lists to, among other things, undercut ClearOne and win sales and harm ClearOne's ability to maintain fair and orderly pricing among its channel partners.

97. ClearOne takes reasonable measures to keep its price lists highly confidential. For example, it includes broad confidentiality provisions in its contracts with manufacturer representatives, dealers, resellers, and distributors to ensure that they do not share the price lists outside of the ClearOne sales channel. Moreover, ClearOne routinely marks the dealer price lists "Confidential" to make it clear that the price lists are not meant to be shared publicly. ClearOne also restricts the dissemination of price lists both internally at ClearOne and externally to manufacturer representatives, dealers, resellers, and distributors. Only employees with express authorization of the Sr. Vice President of Finance and their manager are authorized access to the price lists and, even then, only the specific price lists they require. With respect to external persons, only those specific price lists are shared that will assist the manufacturer representatives, dealers, resellers, and distributors in selling ClearOne products and the e-mail transmittal of the price lists contains language making clear to the recipient that the communication and attachment are confidential.

98. [redacted]

99. [redacted]

[redacted]

100. [redacted] Shure's conduct caused ClearOne to lose sales that it would have otherwise not lost, if not for Shure's misappropriation.

101. [redacted]

102. As a proximate result of Shure's misappropriation, ClearOne has suffered, and will continue to suffer, actual damages, and Shure will be unjustly enriched, in sums not yet ascertained. ClearOne has also suffered and will continue to suffer immediate and irreparable harm and will continue to suffer such injury until the breaches are preliminarily and permanently enjoined.

103. Shure's misappropriation was intentional, malicious, and in bad faith. It has subjected and will continue to subject ClearOne to unjust hardship in conscious disregard of

ClearOne's rights, so as to justify an award of exemplary and punitive damages according to proof at trial. Under the ITSA, ClearOne is entitled to recover its reasonable attorneys' fees as a result of Shure's willful and malicious misappropriation.

PRAYER FOR RELIEF

WHEREFORE, ClearOne respectfully asks that the Court enter judgment against Shure as follows:

A. That Shure has infringed (either literally or under the doctrine of equivalents), directly, jointly, and/or indirectly by way of inducing or contributing to the infringement of, one or more claims of ClearOne's '553 Patent;

B. That Shure's infringement of the '553 Patent was willful;

C. For temporary, preliminary, and permanent injunctive relief enjoining Shure and its officers, directors, agents, affiliates, employees, divisions, branches, subsidiaries, parents, and all others acting in active concert or participation with it, from infringement, inducing the infringement, or contributing to the infringement of the '553 Patent;

D. For an award to ClearOne for its damages, costs, expenses, and prejudgment and post-judgment interest for Shure's infringement of the '553 Patent as provided under 35 U.S.C. §§ 154(d) and 284;

E. For an award to ClearOne for enhanced damages equal to treble the amount of actual damages, for the willful nature of Shure's acts of infringement as to the '553 Patent, with notice being made at least as early as the date of the filing of the SAC, as provided under 35 U.S.C. § 284;

F. That this be declared an exceptional case within the meaning of 35 U.S.C. § 285

and that ClearOne be awarded its reasonable attorneys' fees against Shure;

G. That Shure has misappropriated ClearOne's trade secrets under the DTSA, 18 U.S.C. § 1836, and ITSA, 765 ILCS 1065;

H. For an award of actual loss, unjust enrichment, and/or reasonable royalty under the DTSA, 18 U.S.C. § 1836(b)(3), and ITSA, 765 ILCS 1065/4;

I. For injunctive relief and/or an imposition of a reasonable royalty as compensation for future use, under the DTSA, 18 U.S.C. § 1836(b)(3), and ITSA, 765 ILCS 1065/3;

J. For an award of reasonable attorney's fees under the DTSA, 18 U.S.C. § 1836(b)(3)(D), and ITSA, 765 ILCS 1065/5; and

For any and all other relief to which ClearOne may show itself to be entitled.

Dated: July 30, 2020

By: *_/s/ Douglas J. Dixon_*

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Attorneys for ClearOne, Inc.

EXHIBIT A

US009264553B2

(12) **United States Patent**
Pandey et al.

(10) **Patent No.: US 9,264,553 B2**
(45) **Date of Patent: Feb. 16, 2016**

(54) **METHODS AND APPARATUSES FOR ECHO CANCELATION WITH BEAMFORMING MICROPHONE ARRAYS**

(75) Inventors: **Ashutosh Pandey**, Murray, UT (US); **Darrin T. Thurston**, Liberty, UT (US); **David K. Lambert**, South Jordan, UT (US); **Tracy A. Bathurst**, South Jordan, UT (US)

(73) Assignee: **ClearOne Communications, Inc.**, Salt Lake City, UT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 723 days.

(21) Appl. No.: **13/493,921**

(22) Filed: **Jun. 11, 2012**

(65) **Prior Publication Data**

US 2013/0039504 A1 Feb. 14, 2013

Related U.S. Application Data

(60) Provisional application No. 61/495,961, filed on Jun. 11, 2011, provisional application No. 61/495,968, filed on Jun. 11, 2011, provisional application No. 61/495,971, filed on Jun. 11, 2011.

(51) **Int. Cl.**
H04B 3/20 (2006.01)
H04M 9/08 (2006.01)
H04B 15/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H04M 9/082*** (2013.01)

(58) **Field of Classification Search**
CPC H04R 3/005; H04R 2430/20; H04R 1/406; H04M 9/082; H04M 9/08
USPC 381/66, 71.1, 93; 379/406.01–406.16; 348/14.01
See application file for complete search history.

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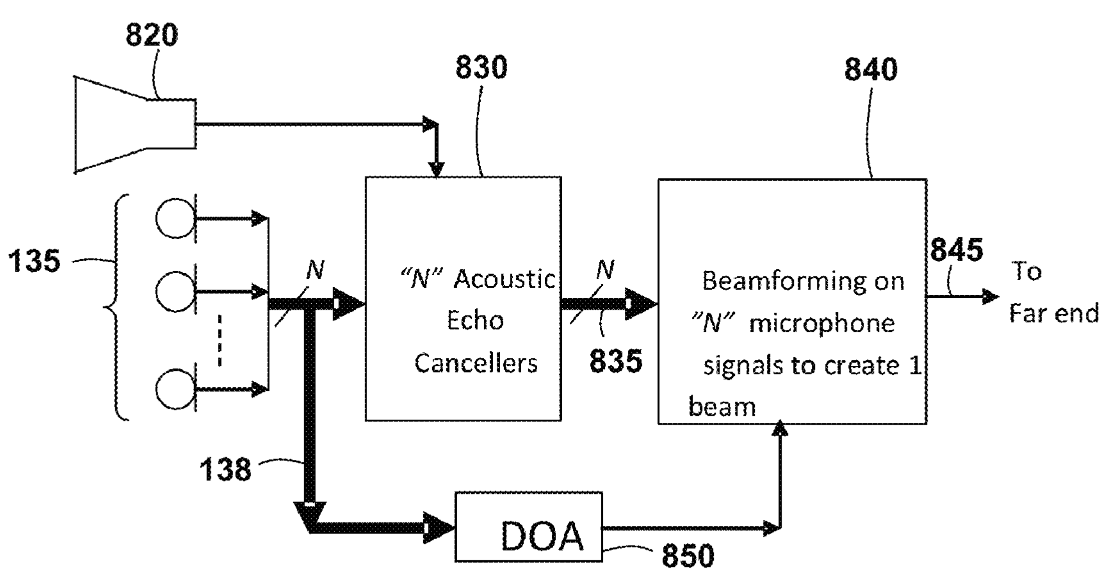
* cited by examiner

Primary Examiner — Vivian Chin
Assistant Examiner — Ammar Hamid
(74) *Attorney, Agent, or Firm* — TraskBritt

(57) **ABSTRACT**

Embodiments include methods and apparatuses for sensing acoustic waves for a conferencing application. A conferencing apparatus includes a plurality of microphones oriented to cover a corresponding plurality of direction vectors and to develop a corresponding plurality of microphone signals. A processor is operably coupled to the plurality of microphones. The processor is configured to perform a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that is greater in number than one and less in number than the plurality of microphone signals. The processor is also configured perform an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals and select one of the plurality of combined echo-canceled signals for transmission.

20 Claims, 10 Drawing Sheets



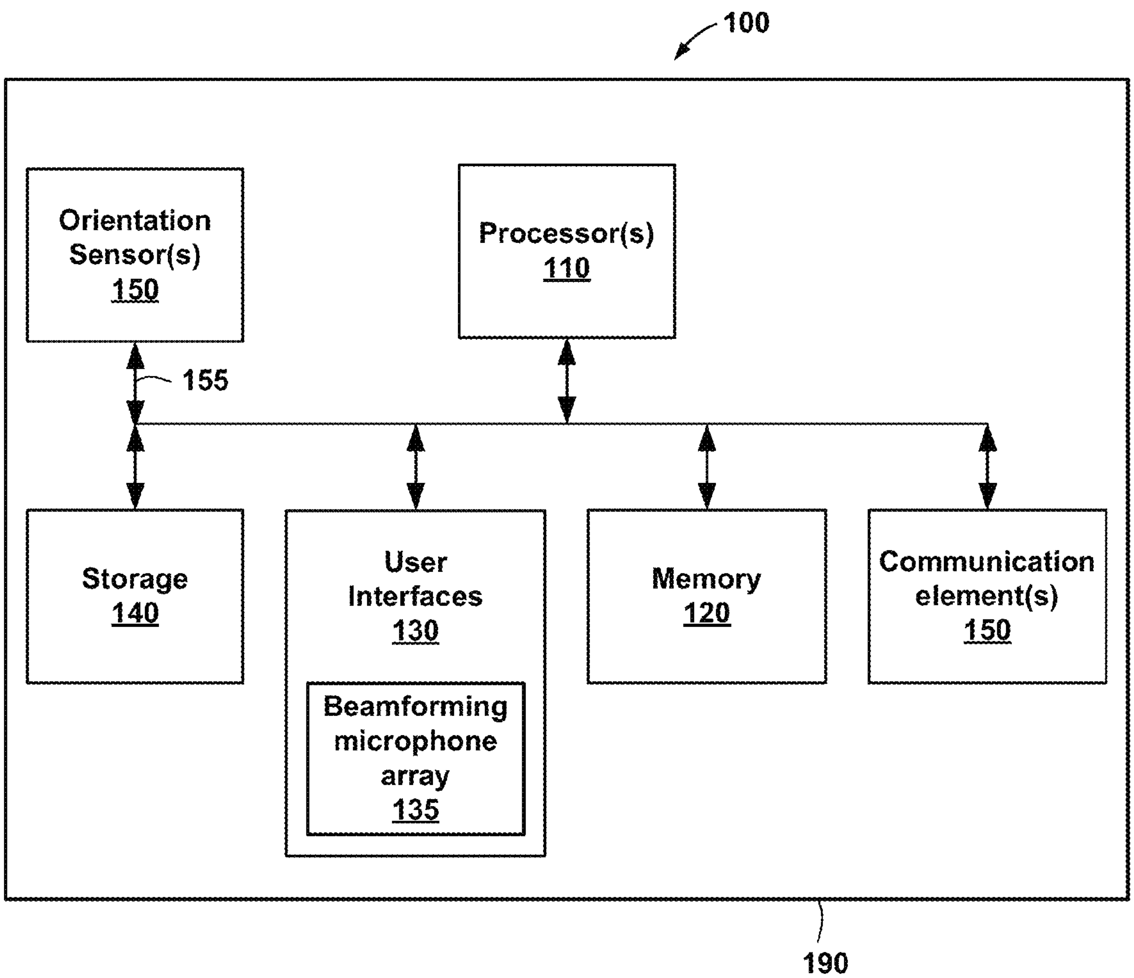

100
Orientation Sensor(s) 150
Processor(s) 110
155
Storage 140
User Interfaces 130
Beamforming microphone array 135
Memory 120
Communication element(s) 150
190

FIG. 1

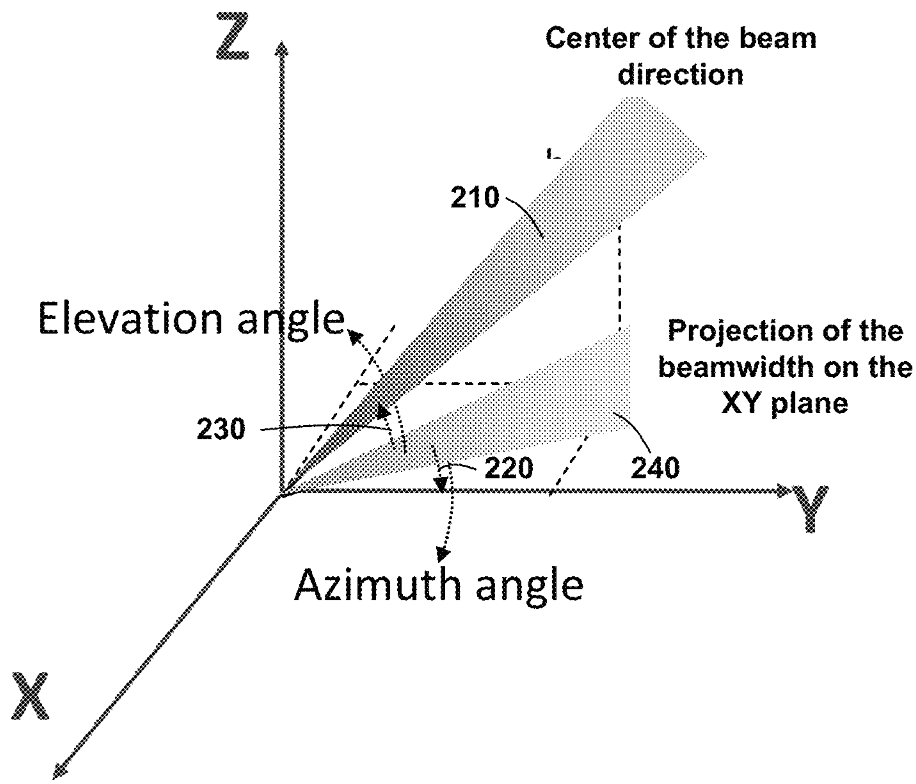

Z
Center of the beam direction
210
Elevation angle
Projection of the beamwidth on the XY plane
230
220
240
Y
Azimuth angle
X

FIG. 2

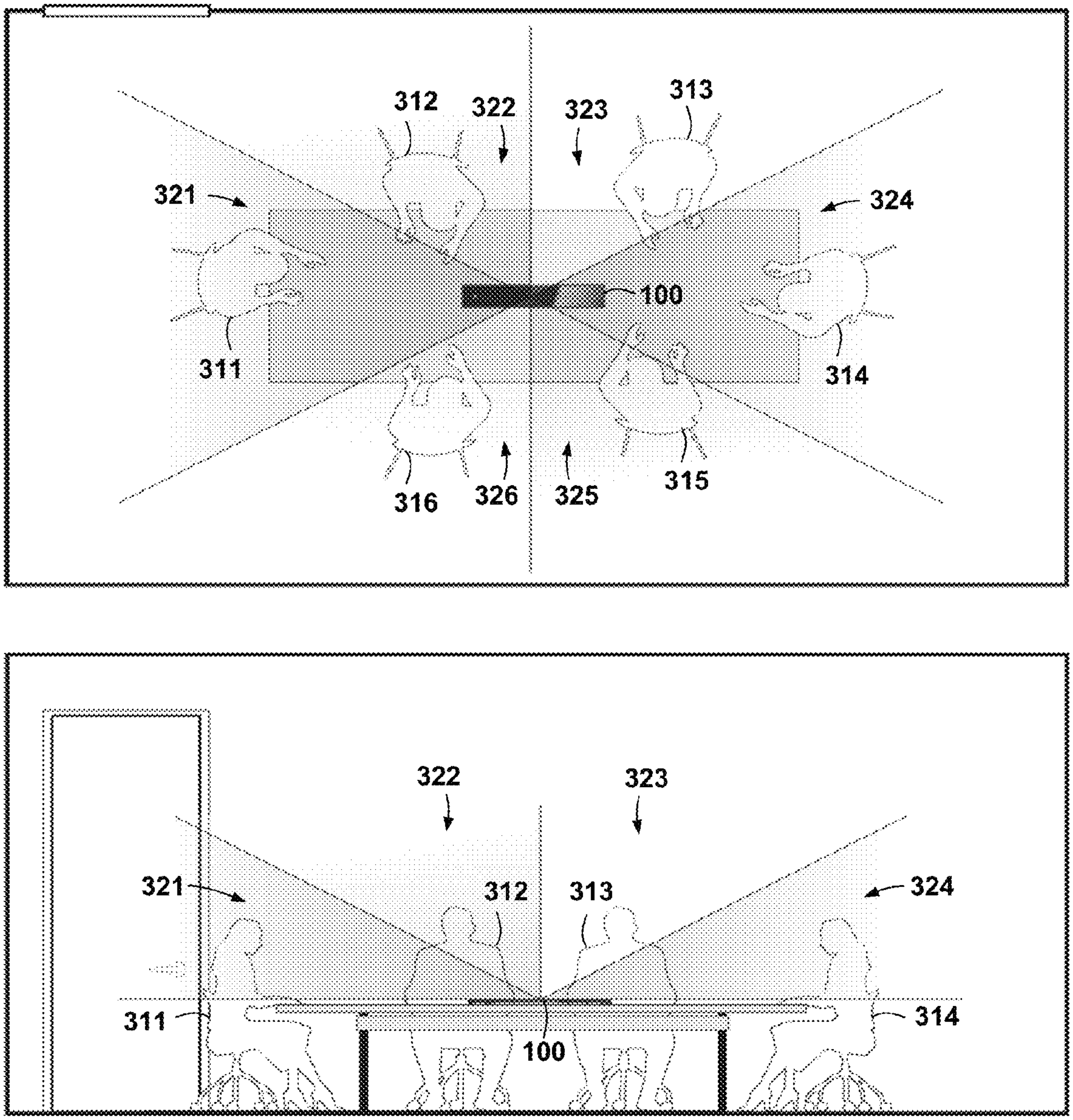

312
322
323
313
321
324
100
311
314
316
326
325
315
322
323
321
312
313
324
311
314
100

FIG. 3

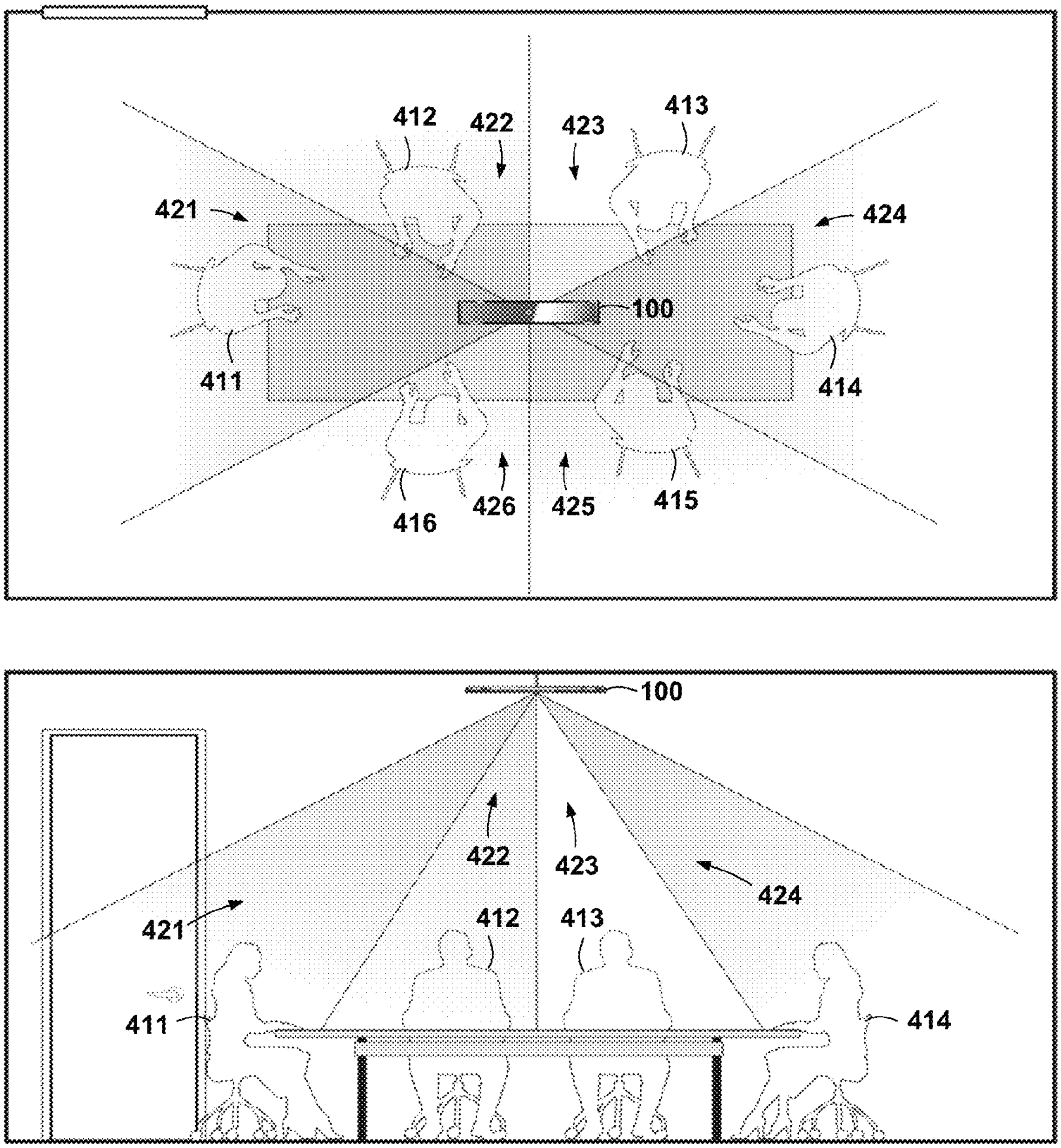

412
422
423
413
421
424
100
411
414
416
426
425
415
100
422
423
424
421
412
413
411
414

FIG. 4

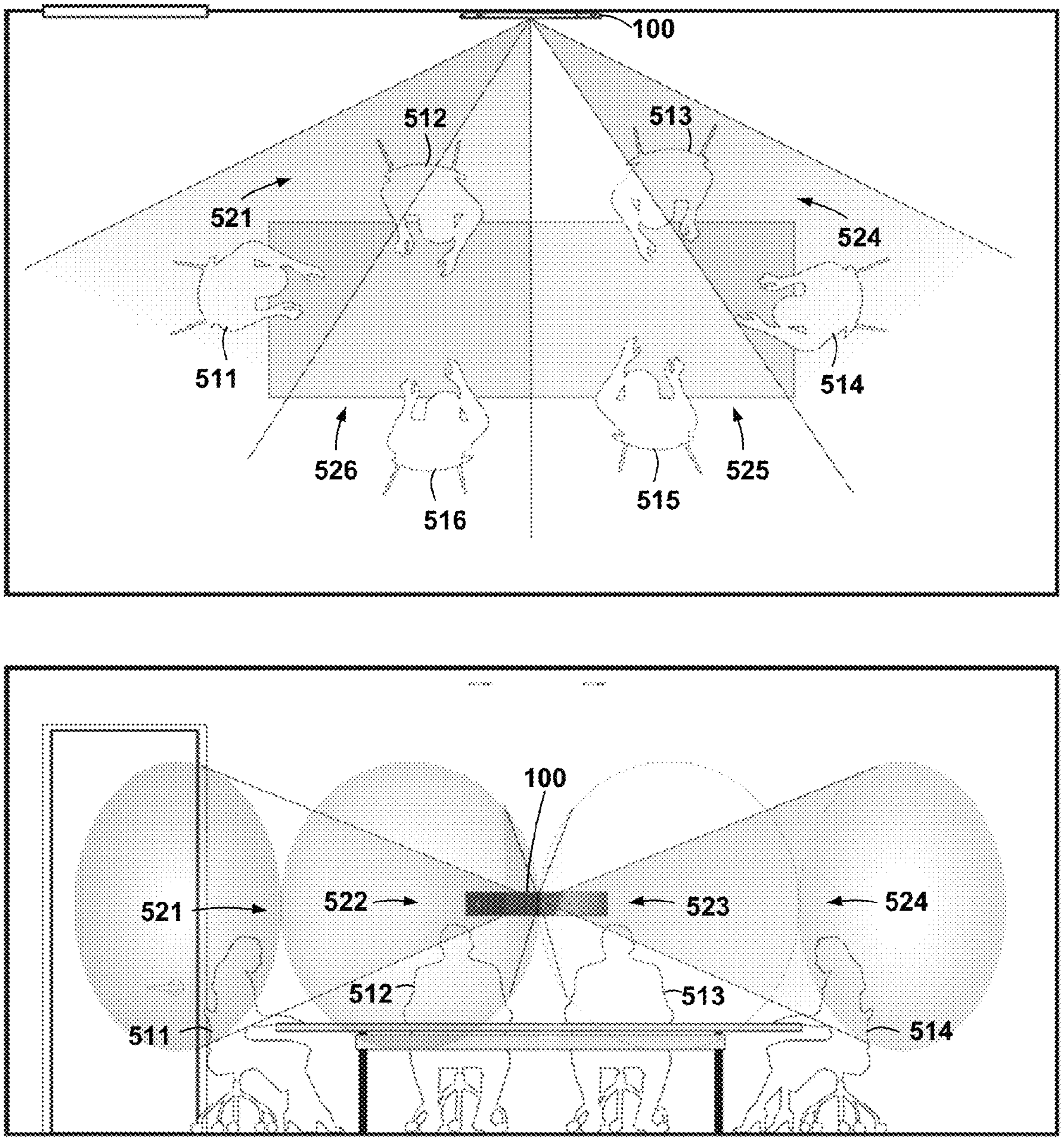

100
512
513
521
524
511
514
526
525
516
515
100
521
522
523
524
512
513
511
514

FIG. 5

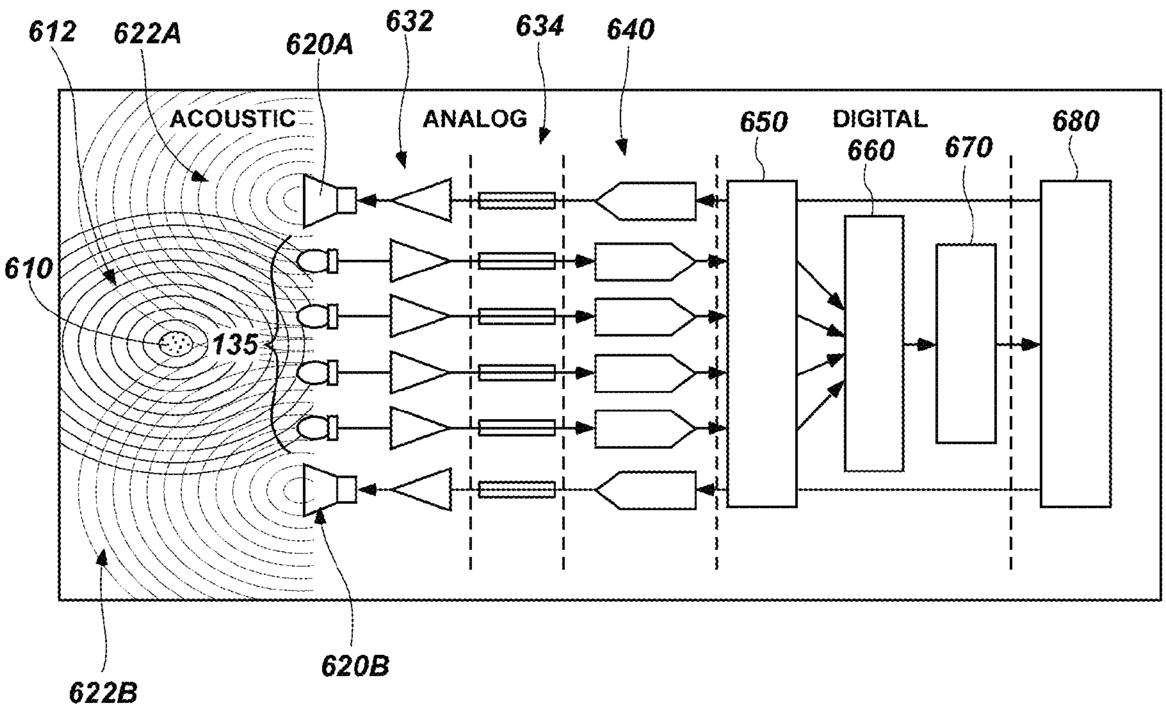

612
622A
620A
632
634
640
ACOUSTIC
ANALOG
650
DIGITAL
660
670
680
610
135
622B
620B

FIG. 6

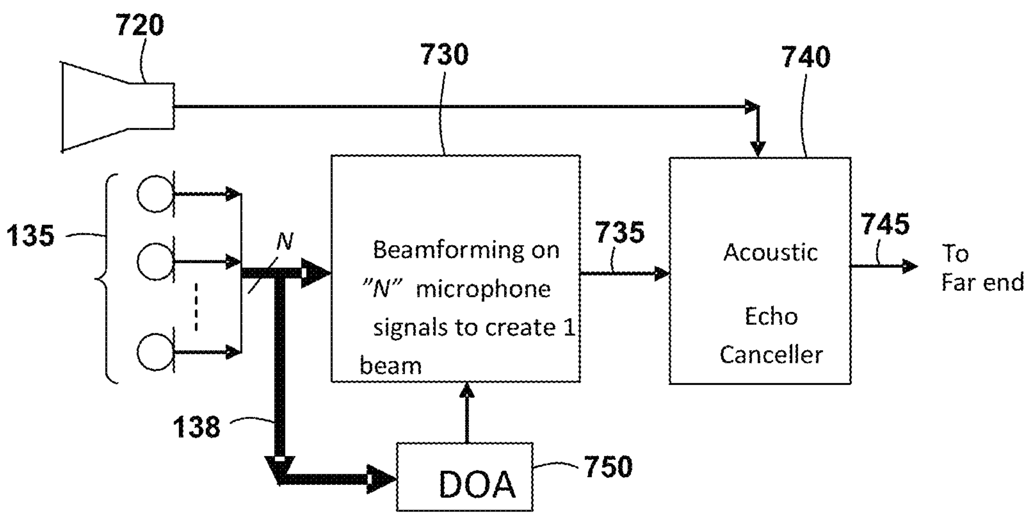

720
730
740
135
N
Beamforming on "N" microphone signals to create 1 beam
735
Acoustic Echo Canceller
745
To Far end
138
DOA
750

FIG. 7

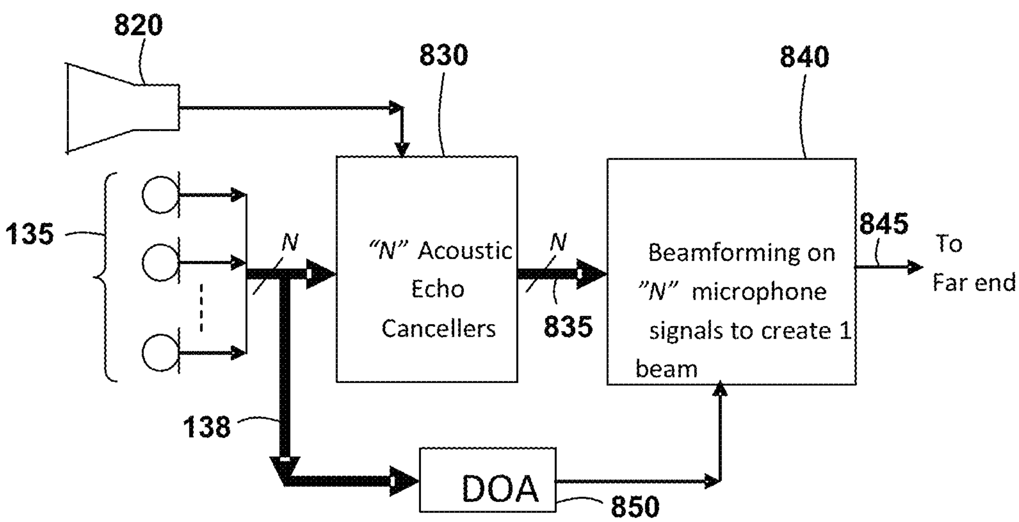

820
830
840
135
N
"N" Acoustic Echo Cancellers
N
835
Beamforming on "N" microphone signals to create 1 beam
845
To Far end
138
DOA
850

FIG. 8

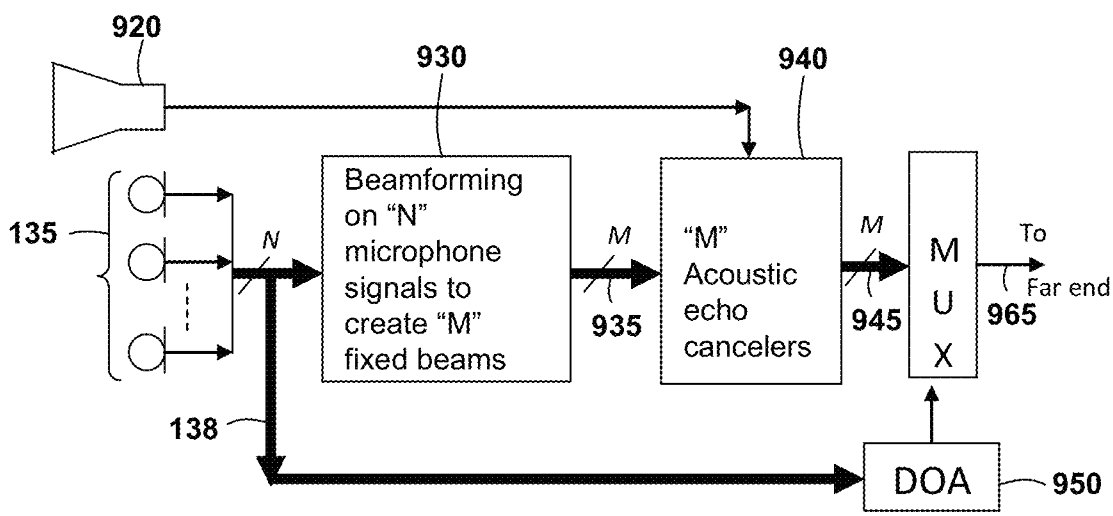

920
930
940
135
N
Beamforming on "N" microphone signals to create "M" fixed beams
M
935
"M" Acoustic echo cancelers
M
945
M U X
To Far end
965
138
DOA
950

FIG. 9

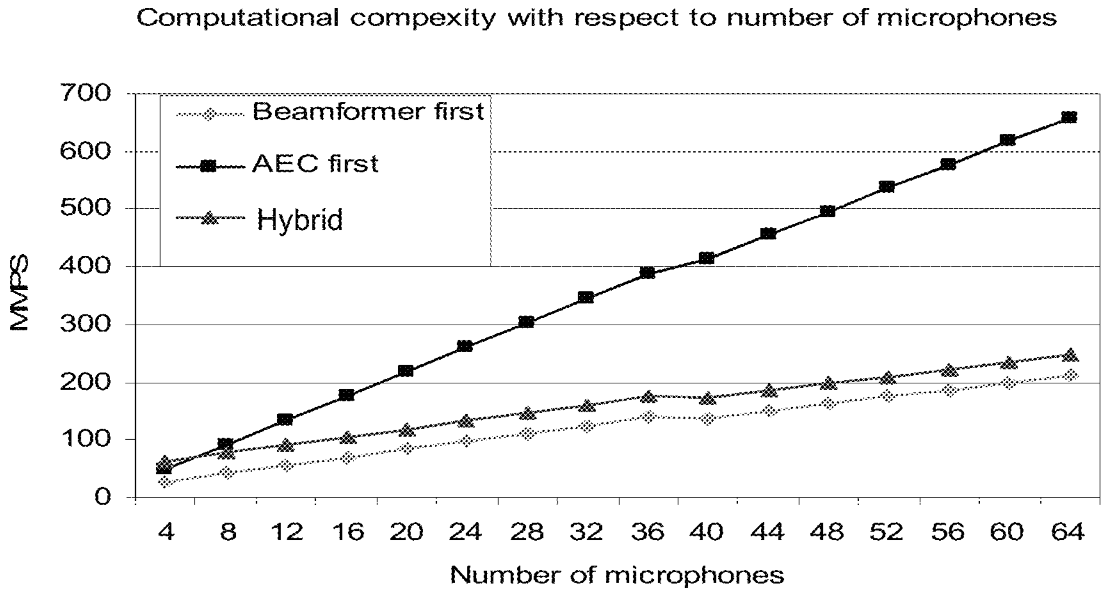

Computational compexity with respect to number of microphones
700
600
500
400
300
200
100
0
MMPS
Beamformer first
AEC first
Hybrid
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Number of microphones

FIG. 10

METHODS AND APPARATUSES FOR ECHO CANCELATION WITH BEAMFORMING MICROPHONE ARRAYS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of: U.S. Provisional Patent Application Ser. No. 61/495,971, filed Jun. 11, 2011 and entitled "Beamforming Microphone Array for Telepresence Application," U.S. Provisional Patent Application Ser. No. 61/495,961, filed Jun. 11, 2011 and entitled "Combining a Beamforming Microphone Array With an Acoustic Echo Canceller for Teleconferencing Applications," and U.S. Provisional Patent Application Ser. No. 61/495,968, filed Jun. 11, 2011 and entitled "Combining a Beamforming Microphone Array With an Acoustic Echo Canceller for Teleconferencing Applications," the disclosures of each of which are incorporated herein in their entirety by this reference.

TECHNICAL FIELD

Embodiments of the present disclosure relate generally to methods and apparatuses for beamforming microphone arrays. More specifically, embodiments of the present disclosure relate to methods and apparatuses with echo cancelation in beamforming microphone arrays.

BACKGROUND

In a typical telepresence application, such as, for example, teleconferencing, a loudspeaker may be located on top, bottom or side of a television set, a microphone may be located in line with the television set and a participant sits in line with a television for the audio conferencing part of it.

Many improvements have been made in teleconferencing and video conferencing systems, which may use microprocessors and software to accomplish a wide variety of system tasks and signal processing algorithms to improve on, compress, and even encrypt video and audio streams. Some teleconferencing applications may include multiple microphones in an array to better capture acoustic patterns of a room and the participants in the room. However, arrayed microphones can cause their own problems with duplicate coverage and echoing.

There is a need for methods and apparatuses to improve on the acoustic quality of microphone arrays with echo cancelation and a need to perform this echo cancelation efficiently.

BRIEF SUMMARY

Embodiments of the present disclosure include methods and apparatuses to improve the acoustic quality of microphone arrays with echo cancelation and perform this echo cancelation efficiently.

Embodiments of the present disclosure include a method of echo cancellation for a conferencing application. The method includes sensing acoustic waves with a plurality of microphones to develop a corresponding plurality of microphone signals. A beamforming operation is performed to combine the plurality of microphone signals to a plurality of combined signals that is greater in number than one and less in number than the plurality of microphone signals. An acoustic echo cancelation operation is performed on the plurality of combined signals to generate a plurality of combined echo-canceled signals and one or more of the plurality of combined echo-canceled signals is selected for transmission.

Embodiments of the present disclosure include a conferencing apparatus. A plurality of microphones are oriented to cover a plurality of direction vectors and to develop a corresponding plurality of microphone signals. A processor is operably coupled to the plurality of microphones. The processor is configured to perform a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that is greater in number than one and less in number than the plurality of microphone signals. The processor is also configured perform an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals and select one or more of the plurality of combined echo-canceled signals for transmission.

Embodiments of the present disclosure include a conferencing apparatus with a beamforming microphone array. Each microphone of the beamforming microphone array is configured to sense acoustic waves from a direction vector substantially different from other microphones in the beamforming microphone array. A memory is configured for storing computing instructions. A processor is operably coupled to the beamforming microphone array and the memory. The processor is configured to execute the computing instructions to perform a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that includes a number of signals between one and a number of signals in the plurality of microphone signals. The processor is also configured to execute the computing instructions to perform an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a conferencing apparatus according to one or more embodiments of the present disclosure;

FIG. **2** illustrates geometrical representations of a beam for a microphone;

FIG. **3** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus disposed on a table and illustrating beams that may be formed by a beamforming microphone array disposed in the conferencing apparatus;

FIG. **4** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus depending from a ceiling and illustrating beams that may be formed by a beamforming microphone array disposed in the conferencing apparatus;

FIG. **5** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus disposed on a wall and illustrating beams that may be formed by a beamforming microphone array disposed in the conferencing apparatus;

FIG. **6** illustrates elements involved in sensing acoustic waves with a plurality of microphones and signal processing that may be performed on the sensed acoustic waves;

FIG. **7** illustrates processing involved in sensing acoustic waves wherein signals from all of the microphones are combined, then acoustic echo cancelation is performed on the combined signal to create a combined echo canceled signal;

FIG. **8** illustrates processing involved in sensing acoustic waves wherein acoustic echo cancelation is performed on signals from each of the microphones, then the echo canceled signals are combined, to create a combined echo canceled signal;

FIG. **9** illustrates processing involved in sensing acoustic waves wherein a subset of signals from the microphones are combined, then acoustic echo cancelation is performed one or more of the combined signals; and

FIG. **10** illustrates computational complexity of various embodiments relative to number of microphones in a beamforming microphone array.

DETAILED DESCRIPTION

In the following description, reference is made to the accompanying drawings in which is shown, by way of illustration, specific embodiments of the present disclosure. The embodiments are intended to describe aspects of the disclosure in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and changes may be made without departing from the scope of the disclosure. The following detailed description is not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

Furthermore, specific implementations shown and described are only examples and should not be construed as the only way to implement or partition the present disclosure into functional elements unless specified otherwise herein. It will be readily apparent to one of ordinary skill in the art that the various embodiments of the present disclosure may be practiced by numerous other partitioning solutions.

In the following description, elements, circuits, and functions may be shown in block diagram form in order not to obscure the present disclosure in unnecessary detail. Additionally, block definitions and partitioning of logic between various blocks is exemplary of a specific implementation. It will be readily apparent to one of ordinary skill in the art that the present disclosure may be practiced by numerous other partitioning solutions. Those of ordinary skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof. Some drawings may illustrate signals as a single signal for clarity of presentation and description. It will be understood by a person of ordinary skill in the art that the signal may represent a bus of signals, wherein the bus may have a variety of bit widths and the present disclosure may be implemented on any number of data signals including a single data signal.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general-purpose processor, a special-purpose processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A general-purpose processor may be considered a special-purpose processor while the general-purpose processor is configured to execute instructions (e.g., software code) stored on a computer-readable medium. A processor may also be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

In addition, it is noted that the embodiments may be described in terms of a process that may be depicted as a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a process may describe operational acts as a sequential process, many of these acts can be performed in another sequence, in parallel, or substantially concurrently. In addition, the order of the acts may be rearranged.

Elements described herein may include multiple instances of the same element. These elements may be generically indicated by a numerical designator (e.g. **110**) and specifically indicated by the numerical indicator followed by an alphabetic designator (e.g., **110**A) or a numeric indicator preceded by a "dash" (e.g., **110-1**). For ease of following the description, for the most part element number indicators begin with the number of the drawing on which the elements are introduced or most fully discussed. For example, where feasible elements in FIG. **3** are designated with a format of **3***xx*, where **3** indicates FIG. **3** and xx designates the unique element.

It should be understood that any reference to an element herein using a designation such as "first," "second," and so forth does not limit the quantity or order of those elements, unless such limitation is explicitly stated. Rather, these designations may be used herein as a convenient method of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not mean that only two elements may be employed or that the first element must precede the second element in some manner. In addition, unless stated otherwise, a set of elements may comprise one or more elements.

Embodiments of the present disclosure include methods and apparatuses to improve the acoustic quality of microphone arrays with echo cancelation and to perform this echo cancelation efficiently.

FIG. **1** illustrates a conferencing apparatus **100** for practicing embodiments of the present disclosure. The conferencing apparatus **100** may include elements for executing software applications as part of embodiments of the present disclosure. Thus, the system **100** is configured for executing software programs containing computing instructions and includes one or more processors **110**, memory **120**, one or more communication elements **150**, and user interface elements **130**. The system **100** may also include storage **140**. The conferencing apparatus **100** may be included in a housing **190**.

The one or more processors **110** may be configured for executing a wide variety of applications including the computing instructions for carrying out embodiments of the present disclosure.

The memory **120** may be used to hold computing instructions, data, and other information for performing a wide variety of tasks including performing embodiments of the present disclosure. By way of example, and not limitation, the memory **120** may include Synchronous Random Access Memory (SRAM), Dynamic RAM (DRAM), Read-Only Memory (ROM), Flash memory, and the like.

Information related to the system **100** may be presented to, and received from, a user with one or more user interface elements **130**. As non-limiting examples, the user interface elements **130** may include elements such as displays, keyboards, mice, joysticks, haptic devices, microphones, speakers, cameras, and touchscreens.

The communication elements **150** may be configured for communicating with other devices or communication networks. As non-limiting examples, the communication elements **150** may include elements for communicating on wired

and wireless communication media, such as for example, serial ports, parallel ports, Ethernet connections, universal serial bus (USB) connections IEEE 1394 ("firewire") connections, Bluetooth wireless connections, 802.1 a/b/g/n type wireless connections, and other suitable communication interfaces and protocols.

The storage **140** may be used for storing relatively large amounts of non-volatile information for use in the computing system **100** and may be configured as one or more storage devices. By way of example, and not limitation, these storage devices may include computer-readable media (CRM). This CRM may include, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tapes, CDs (compact disks), DVDs (digital versatile discs or digital video discs), and other equivalent storage devices.

Software processes illustrated herein are intended to illustrate representative processes that may be performed by the systems illustrated herein. Unless specified otherwise, the order in which the process acts are described is not intended to be construed as a limitation, and acts described as occurring sequentially may occur in a different sequence, or in one or more parallel process streams. It will be appreciated by those of ordinary skill in the art that many steps and processes may occur in addition to those outlined in flow charts. Furthermore, the processes may be implemented in any suitable hardware, software, firmware, or combinations thereof.

When executed as firmware or software, the instructions for performing the processes may be stored on a computer-readable medium. A computer-readable medium includes, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact disks), DVDs (digital versatile discs or digital video discs), and semiconductor devices such as RAM, DRAM, ROM, EPROM, and Flash memory.

By way of non-limiting example, computing instructions for performing the processes may be stored on the storage **140**, transferred to the memory **120** for execution, and executed by the processors **110**. The processor **110**, when executing computing instructions configured for performing the processes, constitutes structure for performing the processes and can be considered a special-purpose computer when so configured. In addition, some or all portions of the processes may be performed by hardware specifically configured for carrying out the processes.

In some embodiments, an orientation sensor **150** may be included. As a non-limiting example, accelerometers configured to sense acceleration in at least two substantially orthogonal directions may be used. As another non-limiting example, a multi-axis accelerometer may be used. Of course, other types of position sensors may also be used, such as for example magnetometers to sense magnetic fields of the Earth.

Single- and multi-axis models of accelerometers may be used to detect magnitude and direction of the proper acceleration (i.e., g-force), and can be used to sense orientation. Orientation can be sensed because gravity acting on the accelerometers can detect direction of weight changes. The proper acceleration measured by an accelerometer is the acceleration associated with the phenomenon of weight experienced by any mass at rest in the frame of reference of the accelerometer device. For example, an accelerometer can measure a value of "g" in the upward direction when remaining stationary on the ground, because masses on the Earth have weight (i.e., mass*g). Another way of stating this phenomenon is that by measuring weight, an accelerometer measures the acceleration of the free-fall reference frame (i.e., the inertial reference frame) relative to itself.

One particular type of user interface element **130** used in embodiments of the present disclosure is a plurality of microphones **135**, which can be configured as a beamforming microphone array **135**.

Thus, accelerometers mounted in the housing **190** can be used to determine the orientation of the housing **190**. With the beamforming microphone array **135** also mounted in the housing **190**, the orientation of the beamforming microphone array **135** is easily determined because it is in a fixed position relative to the housing.

Microphones are often used in a teleconference to capture participant's audio. In a teleconference, microphones are usually placed on a table or hanged from ceiling and are manually positioned so that a participant audio is in the pick-up pattern of the microphone. Since, pick-up patterns of these microphones are fixed, more often than not one type of microphone, say a tabletop microphone, may not work for another type of installation, say a ceiling installation. Thus, an installer may need to know the type of installation (e.g., tabletop or ceiling), angle of participant's relative to the microphones, and the number of participants before installing a correct set of microphones.

In some embodiments of the present disclosure, the conferencing apparatus **100** uses a beamforming microphone array **135** that can be installed in a number of positions and configuration and beams for the microphones can be adjusted with base level configurations or automatically and adaptively bring participants into the pick-up pattern of the beamforming microphone array **135** based on the orientation and placement of the conferencing apparatus **100**.

Microphones may be used in conferencing applications to perform spatial filtering to improve audio quality. These microphones have a beam pattern that selectively picks up acoustic waves in a region of space and rejects others.

FIG. **2** illustrates geometrical representations of a beam for a microphone. A direction vector **210** of the beam extends from the microphone. The beam pattern for a microphone is usually specified with an azimuth angle **220**, an elevation angle **230**, and a beamwidth **240**. Of course, the beamwidth **240** will have a three-dimensional quality to it and FIG. **2** illustrates a projection of the beam width **240** onto the X-Y plane. Not only should a participant face a microphone, the location of the participant's mouth relative to the microphone should be in the beam pattern as well for good quality of the participant's audio.

Beamforming is a signal processing technique carried out by the processor **110** using input from the beamforming microphone array **135**. Various signal-processing characteristics of each of the microphones in the beamforming microphone array **135** may be modified. The signals from the various microphones may be combined such that that signals at particular angles experience constructive interference while others experience destructive interference. Thus, beamforming can be used to achieve spatial selectivity such that certain regions can be emphasized (i.e., amplified) and other regions can be de-emphasized (i.e., attenuated). As a non-limiting example, the beam-forming processing may be configured to attenuate sounds that originate from the direction of a door to a room.

Beamforming may use interference patterns to change the directionality of the array. In other words, information from the different microphones may be combined in a way where the expected pattern of radiation is preferentially observed. Beamforming techniques may involve combining delayed signals from each microphone at slightly different times so that every signal reaches the output at substantially the same time.

Moreover, signals from each microphone may be amplified by a different amount. Different weighting patterns may be used to achieve the desired sensitivity patterns. As a non-limiting example, a main lobe may be produced together with nulls and sidelobes. As well as controlling the main lobe width (the beam) and the sidelobe levels, the position of a null can be controlled. This is useful to ignore noise in one particular direction, while listening for events in other directions. Adaptive beamforming algorithms may be included to automatically adapt to different situations.

Embodiments of the present disclosure include a beamforming microphone array, where elevation angle of the beam can be programmed with software default settings or automatically adapted for an application. In some embodiments, various configurations for the conferencing apparatus, such as tabletop, ceiling, and wall configurations can be automatically identified with the orientation sensor **150** in the conferencing apparatus **100**.

FIG. **3** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus **100** disposed on a table and illustrating beams that may be formed by a beamforming microphone array **135** disposed in the conferencing apparatus **100**. Beams **321**, **322**, **323**, **324**, **325**, and **326** can be configured with direction, beamwidth, amplification levels, and interference patterns to obtain quality coverage of participants, **311**, **312**, **313**, **314**, **315**, and **316**, respectively.

FIG. **4** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus **100** depending from a ceiling and illustrating beams that may be formed by a beamforming microphone array **135** disposed in the conferencing apparatus. Beams **421**, **422**, **423**, **424**, **425**, and **426** can be configured with direction, beamwidth, amplification levels, and interference patterns to obtain quality coverage of participants, **411**, **412**, **413**, **414**, **415**, and **416**, respectively.

FIG. **5** illustrates a top view and a side view of a conference room including participants and a conferencing apparatus **100** disposed on a wall and illustrating beams that may be formed by the beamforming microphone array **135** disposed in the conferencing apparatus **100**. Beams **521**, **522**, **523**, **524**, **525**, and **526** can be configured with direction, beamwidth, amplification levels, and interference patterns to obtain quality coverage of participants, **511**, **512**, **513**, **514**, **515**, and **516**, respectively.

In FIGS. **3**-**5**, the azimuth angles and beamwidths may be fixed to cover desired regions. As a non-limiting example, the six beams illustrated in FIG. **3** and FIG. **4** can each be configured with beamwidths of 60 degrees with the beamforming microphone array **135**. The elevation angle of each beam is designed to cover most people sitting at a table. As a non-limiting example, an elevation angle of 30 degrees may cover most tabletop applications. On the other hand, for a ceiling application, the elevation angle is usually higher as shown in FIG. **4**. As a non-limiting example, an elevation angle closer to 60 degrees may be appropriate for a ceiling application. Finally, for a wall application, as shown in FIG. **5**, the elevation angle may be appropriate at or near zero degrees.

While these default elevation angles may be defined for each of the orientations, the user, installer, or both, have flexibility to change the elevation angle with software settings at the time of installation, before a conference, or during a conference.

A beamforming microphone array substantially improves audio quality in teleconferencing applications. Furthermore, some embodiments of the present disclosure use a teleconferencing solution with a beamforming microphone array that incorporates acoustic echo cancelation (AEC) to enhance full duplex audio quality.

For high quality in teleconferencing applications, audio of the far-end participant picked up by microphones of the beamforming microphone array **135** can be canceled before transmitting. This is achieved by an acoustic echo canceler (AEC) that uses the loudspeaker audio of the far-end participant as a reference. In the case of the beamforming microphone array **135**, there are multiple ways of doing acoustic echo cancelation in combination with beamforming.

Two strategies, "AEC first" and "beamformer first," have been proposed to combine an acoustic echo canceler with a beamforming microphone array. The "beamformer first" method performs beamforming on microphone signals and subsequently echo cancelation is applied on the beamformed signals. The "beamformer first" method is relatively computational friendly but requires continuous learning in the echo canceler due to changing characteristics of the beamformer. Often these changes renders the "beamformer first" method impractical for good conferencing systems.

On the other hand, an "echo canceler first" system applies echo cancelation on each microphone signal and subsequently beamforming is applied on the echo canceled signals. The "AEC first" system provides better echo cancelation performance but is computationally intensive as the echo cancelation is applied for every microphone in the microphone array. The computational complexity increases with an increase in the number of microphones in the microphone array. This computational complexity often limits the number of microphones used in a microphone array and therefore prevents achievement of the substantial benefit from the beamforming algorithm with more microphones.

Embodiments of the present disclosure implement a conferencing solution with beamformer and echo canceler in a hybrid configuration with a "beamformer first" configuration to generate a number of fixed beams followed by echo cancelers for each fixed beam. This hybrid configuration allows an increase in the number of microphones for better beamforming without the need for additional echo cancelers as the number of microphones is increased. Also, the echo cancelers do not need to continually adapt because as the number of fixed beams may be held constant. Therefore, embodiments of the present disclosure provide good echo cancelation performance and the increase in the computational complexity for large number microphones is smaller than the "AEC first" methods.

FIG. **6** illustrates elements involved in sensing acoustic waves with a plurality of microphones and signal processing that may be performed on the sensed acoustic waves. In an acoustic environment on the left of FIG. **6**, an acoustic source **610** (e.g., a participant) may generate acoustic waves **612**. In addition, speakers **620**A and **620**B may generate acoustic waves **622**A and **622**B, respectively. A beamforming microphone array **135** senses the acoustic waves (**612**, **622**A, and **622**B). Amplifiers **634** may filter and modify the analog signals to the speakers **620**A and **620**B and from the beamforming microphone array **135**. Converters **640** in the form of analog-to-digital converters and digital-to-analog converters convert signals between the analog domain and the digital domain. Various signal-processing algorithms may be performed on the digital signals, such as, for example, acoustic echo cancelation **650**, beamforming **660**, and noise suppression **670**. Resulting digital signals may be then transmitted, such as, for example through a voice over Internet Protocol application **680**.

Broadly, two configurations for the signal processing may be considered: "beamformer first" and "echo canceler first." FIG. **5** illustrates an echo canceler first configuration. The following discussion concentrates primarily on the signal processing operations and how beamforming and acoustic echo cancelation may be performed in various configurations. Generally, in FIGS. **7** through **9** thicker lines represent multichannel signals with the number of lines illustrated, whereas thinner lines represent a single channel signal.

FIG. **7** illustrates processing involved in sensing acoustic waves wherein signals from all of the microphones are combined, then acoustic echo cancelation is performed on the combined signal to create a combined echo canceled signal. The beamforming microphone array **135** generates a set of N microphone signals **138**. This "beamformer first" configuration uses the microphone signals **138** to define a beam in the direction indicated by a direction-of-arrival (DOA) determination process **750**. The DOA determination process **750** directs a beamforming process **730** to properly combine the microphone signals **138** into a combined signal **735**. An acoustic echo canceler **740** then performs acoustic echo cancelation on the combined signal **735** to create a combined echo-canceled signal **745**.

FIG. **8** illustrates processing involved in sensing acoustic waves wherein acoustic echo cancelation is performed on signals from each of the microphones, then the echo canceled signals are combined, to create a combined echo-canceled signal. The beamforming microphone array **135** generates a set of N microphone signals **138**. In this "AEC first" configuration, an acoustic echo cancel process **830** performs acoustic echo cancelation on each microphone signal **138** separately. Thus, a set of N echo-canceled signals **835** are presented to a beamforming process **840**. A DOA determination process **850** directs a beamforming process **840** to properly combine the echo-canceled signals **835** into a combined echo-canceled signal **845**. Since echo is canceled beforehand in the "AEC first" method, the echo canceler performance is not affected by beam switches. On the other hand, the "AEC first" configuration first cancels the echo from the audio of each microphone and the beam is created from N echo-canceled signals in the direction pointed to by the DOA determination process **850**. In terms of spatially filtering the audio, both configurations are substantially equivalent.

However, echo cancelation performance can be significantly different from one application to another. Specifically, as the beam is moving, the echo canceler needs to readjust. In a typical conferencing situation, talker directions keep switching and, therefore, the echo canceler needs to readjust, which may result into residual echo in the audio sent to the far end.

While the "AEC first" configuration provides acceptable performance for the beamformer/AEC implementation, the computational complexity of this configuration is significantly higher than the "beamformer first" configuration. Moreover, the computation complexity to implement the "AEC first" configuration increases significantly as the number of microphones used to create beam increases. Therefore, for given computational complexity, the maximum number of microphones that can be used for beamforming is lower for the "AEC first" configuration than the "beamformer first" configuration. Using comparatively more number of microphones can increase audio quality of the participants, especially when a participant moves farther away from the microphones.

FIG. **9** illustrates processing involved in sensing acoustic waves wherein a subset of signals from the microphones are combined, then acoustic echo cancelation is performed one or more of the combined signals. The beamforming microphone array **135** generates a set of N microphone signals **138**. In this hybrid configuration, a beamforming process **930** forms M fixed beams **935** from N microphone signals **138**. An acoustic echo cancel process **940** performs acoustic echo cancelation on each of the M fixed beams **935** separately. As a result M combined echo-canceled signals **945** are generated. A multiplexer **960** controlled by the DOA determination process **950** selects one or more of the M combined echo-canceled signals **945** as final output signals **965**.

In order to balance computation complexity of the complete system and number of microphones to do beamforming, the configuration of FIG. **9** creates M combined echo-canceled signals **945** to present as the final output signals **965**.

In teleconferencing application including beamforming, increasing the number of beams does not add as much benefit as increasing the number of microphones. Therefore, while a large number of microphones may be used to create good beam pattern in the hybrid configuration, the increase in computational complexity due to additional echo cancelers is significantly smaller than the "AEC first" configuration. Furthermore, since the beam is selected after the echo cancelation, echo cancelation performance is not affected due to change in the beam location. It should be noted that the number of echo cancelers does not need to change with a changing number of microphones. Furthermore, since the beamforming is done before the echo cancelation, the echo canceler also performs better than the "AEC first" setup.

FIG. **10** illustrates computational complexity of various embodiments relative to number of microphones in a beamforming microphone array. The computational complexity for various configurations and number of microphones was calculated in terms of required million-multiplications per second (MMPS) and is shown in FIG. **10**. It can be seen that the computational complexity for all methods increase as the number of microphones increase. However, the increase in the computational complexity for the "beamformer first" configuration and the hybrid configuration is much smaller than that of the "AEC first" configuration. With low computational complexity, and the fact that the implementation of the hybrid configuration has less chance of errors in the echo cancelation as a talker's direction switches, the hybrid configuration a good balance between quality and computational complexity for audio conferencing systems.

While the present disclosure has been described herein with respect to certain illustrated embodiments, those of ordinary skill in the art will recognize and appreciate that the present invention is not so limited. Rather, many additions, deletions, and modifications to the illustrated and described embodiments may be made without departing from the scope of the invention as hereinafter claimed along with their legal equivalents. In addition, features from one embodiment may be combined with features of another embodiment while still being encompassed within the scope of the invention as contemplated by the inventor.

What is claimed is:

1. A method of echo cancellation for a conferencing application, comprising:

sensing acoustic waves with a plurality of microphones to develop a corresponding plurality of microphone signals;

performing a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that is greater in number than one and less in number than the plurality of microphone signals, each of the plurality of combined signals corresponding to a different fixed beam;

performing an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals; and

selecting one or more of the plurality of combined echo-canceled signals for transmission.

2. The method of claim **1**, further comprising performing a direction-of-arrival determination on the plurality of microphone signals and wherein selecting one or more of the plurality of combined echo-canceled signals is performed responsive to the direction-of-arrival determination.

3. The method of claim **1**, wherein sensing the acoustic waves with the plurality of microphones comprises sensing the acoustic waves with a beamforming microphone array.

4. The method of claim **1**, further comprising noise filtering the plurality of combined signals prior to performing the acoustic echo cancelation operation.

5. The method of claim **1**, further comprising noise filtering the selected one or more of the plurality of combined echo-canceled signals.

6. The method of claim **1**, further comprising transmitting the selected one or more of the plurality of combined echo-canceled signals.

7. The method of claim **1**, further comprising:

sensing an orientation of a housing bearing the plurality of microphones; and

automatically adjusting a signal-processing characteristic of one or more of the microphones responsive to the sensed orientation.

8. A conferencing apparatus, comprising:

a plurality of microphones oriented to cover a plurality of direction vectors to develop a corresponding plurality of microphone signals; and

a processor operably coupled to the plurality of microphones and configured to:

perform a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that is greater in number than one and less in number than the plurality of microphone signals, each of the plurality of combined signals corresponding to a different fixed beam;

perform an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals; and

select one or more of the plurality of combined echo-canceled signals for transmission.

9. The conferencing apparatus of claim **8**, wherein the processor is further configured to perform a direction-of-arrival determination on the plurality of microphone signals and wherein selecting one or more of the plurality of combined echo-canceled signals is performed responsive to the direction-of-arrival determination.

10. The conferencing apparatus of claim **8**, wherein the plurality of microphones are configured as a beamforming microphone array.

11. The conferencing apparatus of claim **8**, wherein the processor is further configured to noise filter the selected one or more of the plurality of combined echo-canceled signals.

12. The conferencing apparatus of claim **8**, wherein the processor is further configured to noise filter the plurality of combined signals prior to performing the acoustic echo cancelation operation.

13. The conferencing apparatus of claim **8**, wherein the processor is further configured to transmit the selected one or more of the plurality of combined echo-canceled signals.

14. The conferencing apparatus of claim **8**, further comprising an orientation sensor configured to generate an orientation signal indicative of an orientation of a housing bearing the plurality of microphones and wherein the processor is further configured to execute the computing instructions to automatically adjust a signal-processing characteristic of one or more of the microphones responsive to the orientation signal.

15. A conferencing apparatus, comprising:

a beamforming microphone array for developing a plurality of microphone signals, each microphone of the beamforming microphone array is configured to sense acoustic waves from a direction vector substantially different from other microphones in the beamforming microphone array;

a memory configured for storing computing instructions; and

a processor operably coupled to the beamforming microphone array and the memory, the processor configured to execute the computing instructions to:

perform a beamforming operation to combine the plurality of microphone signals to a plurality of combined signals that includes a number of signals between one and a number of signals in the plurality of microphone signals, each of the plurality of combined signals corresponding to a different fixed beam; and

perform an acoustic echo cancelation operation on the plurality of combined signals to generate a plurality of combined echo-canceled signals.

16. The conferencing apparatus of claim **15**, wherein the processor is further configured to perform a direction-of-arrival determination on the plurality of microphone signals and select one or more of the plurality of combined echo-canceled signals responsive to the direction-of-arrival determination.

17. The method of claim **16**, further comprising transmitting the selected one or more of the plurality of combined echo-canceled signals.

18. The conferencing apparatus of claim **15**, further comprising an orientation sensor configured to generate an orientation signal indicative of an orientation of the beamforming microphone array and wherein the processor is further configured to execute the computing instructions to automatically adjust a signal-processing characteristic of one or more of the microphones responsive to the orientation signal.

19. The conferencing apparatus of claim **18**, wherein the processor is further configured to execute the computing instructions to automatically adjust a number of the microphones participating in the beamforming microphone array responsive to the orientation signal.

20. The conferencing apparatus of claim **18**, wherein the processor is further configured to execute the computing instructions to automatically adjust at least one microphone of the beamforming microphone array by adjusting a signal-processing characteristic selected from the group consisting of an amplification level, the direction vector, an interference pattern with another directional microphone of the beamforming microphone array, or a combination thereof.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,264,553 B2
APPLICATION NO. : 13/493921
DATED : February 16, 2016
INVENTOR(S) : Ashutosh Pandey et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification

In column 6, line 51, delete “that that” and insert -- that --, therefor.

In column 8, line 55, delete “622B,” and insert -- 622B --, therefor.

In the claims

In column 12, line 39, in claim 17, delete “method” and insert -- conferencing apparatus --, therefor.

Signed and Sealed this
Tenth Day of May, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

EXHIBIT B

[redacted]

EXHIBIT C

[redacted]

EXHIBIT D

[redacted]

EXHIBIT E

[redacted]

EXHIBIT F

[redacted]

EXHIBIT G

[redacted]

[redacted]

EXHIBIT H

Main Overview

General Description

The Microflex® Advance™ table array is a premium networked tabletop microphone for AV conferencing environments, including boardrooms, huddle rooms and multi-purpose spaces. Revolutionary technology from the IntelliMix® DSP suite includes Steerable Coverage™ , with selectable polar patterns on four independent channels to capture participant audio. The innovative new toroid polar pattern delivers 360° coverage, while rejecting sound from directly above the microphone. Browser-based control software provides an intuitive user interface for microphone attributes, including channel configuration, automatic mix settings, and preset templates. The microphone integrates seamlessly with Dante™ digital networked audio and third-party preset controllers, including Crestron and AMX, to deliver a high-quality AV Conferencing experience that appeals equally to integrators, consultants, and meeting participants.

Features

Configurable Coverage

- Steerable Coverage™ delivers precise pick-up for up to 4 independent lobes
- IntelliMix® DSP Suite provides fast-acting automatic mixing and channel equalization
- Innovative toroid polar pattern delivers 360° coverage, while rejecting sound from directly above the microphone to reduce noise caused by HVAC systems or video projectors.

Software Control

- Intuitive software interface provides comprehensive microphone and pattern control
- Includes templates to speed initial set-up and 10 customizable presets to import or export configurations between multiple microphones

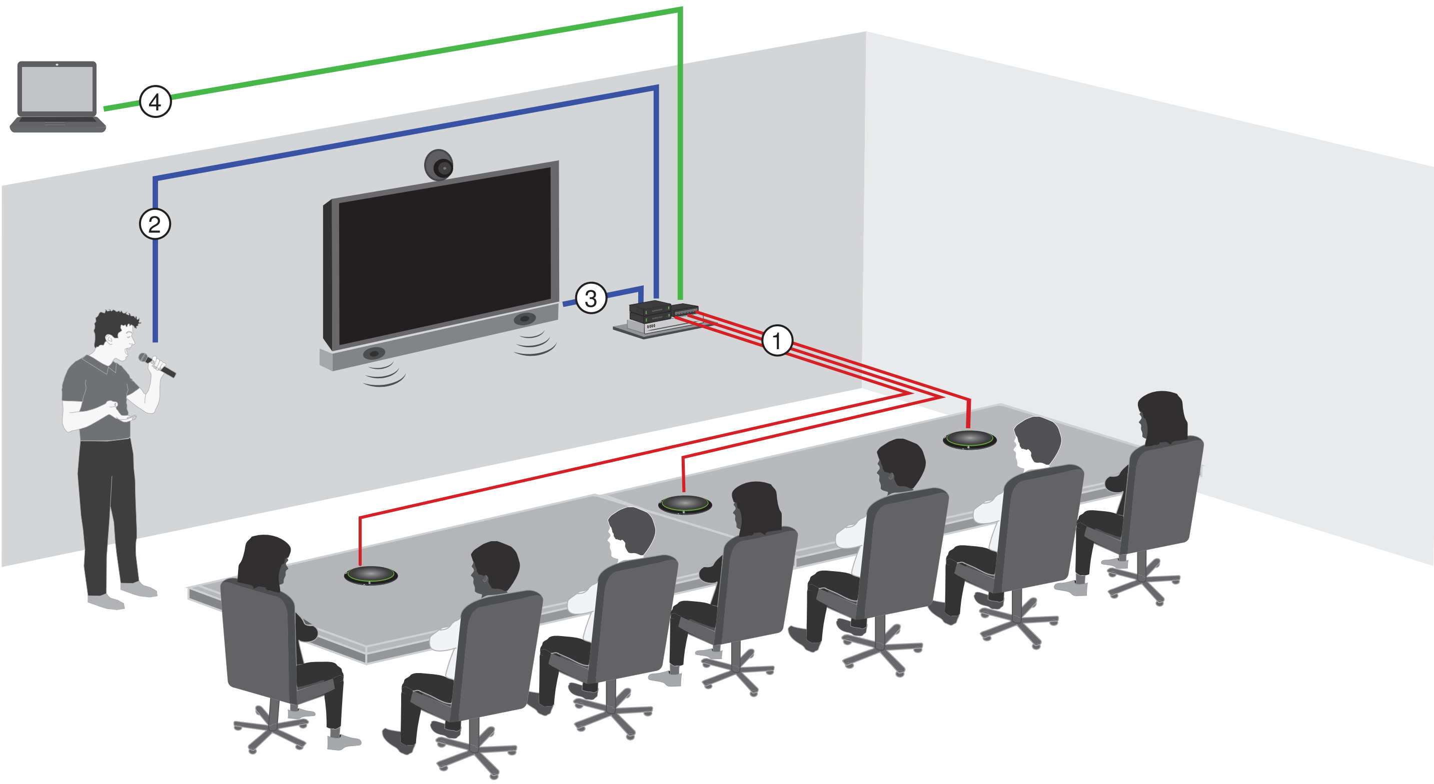
Network Connectivity

- Four discrete audio channels and an additional automix channel are delivered over a single network cable
- Dante™ digital audio coexists safely on the same network as IT and control data, or can be configured to use a dedicated network
- Control strings available for third-party preset controllers including Crestron and AMX

Professional Design

- Sleek, low-profile industrial design blends with contemporary board rooms and meeting spaces
- Configurable multi-colored LED light ring matches the environment, displays mute settings, and confirms coverage settings
- Available in white, black, and aluminum finishes

System Overview



① Dante™ audio, power, and control
A single network cable delivers 4 discrete audio channels from each microphone onto the Dante network, where they can be routed to any Dante™ -compatible devices.

② Analog audio (microphone to network)
Analog equipment, such as a wireless microphone system or a gooseneck microphone on a podium, connects to the Dante™ audio network through a Shure Network Interface (model ANI4IN) for a completely networked conferencing system.

③ Far-end audio (network to loudspeakers)
Dante™-enabled loudspeakers and amplifiers connect directly to a network switch. Analog loudspeakers and amplifiers connect through a Shure Network Interface (model ANI4OUT), which converts Dante™ audio channels into analog signals, delivered through 4 discrete XLR or block connector outputs.

④ Device control and Dante™ audio
A computer running Dante™ Controller and the Shure browser-based interface provides control over the following:

System Planning and Gear Requirements

Setting up the Audio Network

Shure networked conferencing systems are comprised of Microflex Advance microphones and network interfaces, which operate entirely on a Dante™ network. Additional hardware, including network switches, computers, loudspeakers, and audio processors are described in the hardware component index.

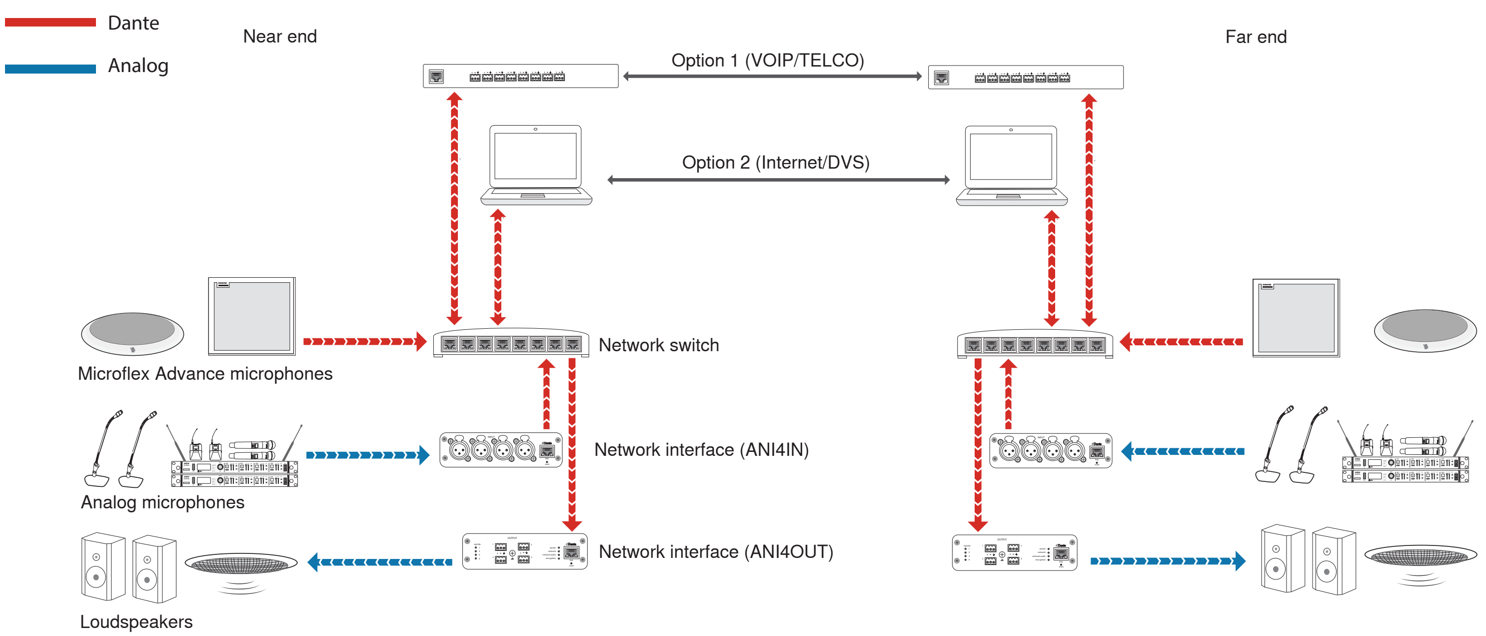
Shure components shown in this diagram:

Microflex Advance Microphones
The MXA910 and MXA310 are equipped with Dante outputs, and connect directly to a network switch.

Audio Network Interfaces
The interfaces are used to connect analog devices such as loudspeakers and analog microphones to the network.

ANI4IN: Converts 4 analog signals (separate XLR and block connector models available) into Dante™ digital audio signals.

ANI4OUT: Converts 4 channels of Dante™ audio from the network into analog signals.



This diagram shows the entire signal path through a networked conference system. Signals from the near end and far end are exchanged through an audio processor connected to a phone system, or through a computer connected to the internet. Analog microphones connect to the network through the Shure ANI4IN, while loudspeakers connect through the Shure ANI4OUT.

EXHIBIT I

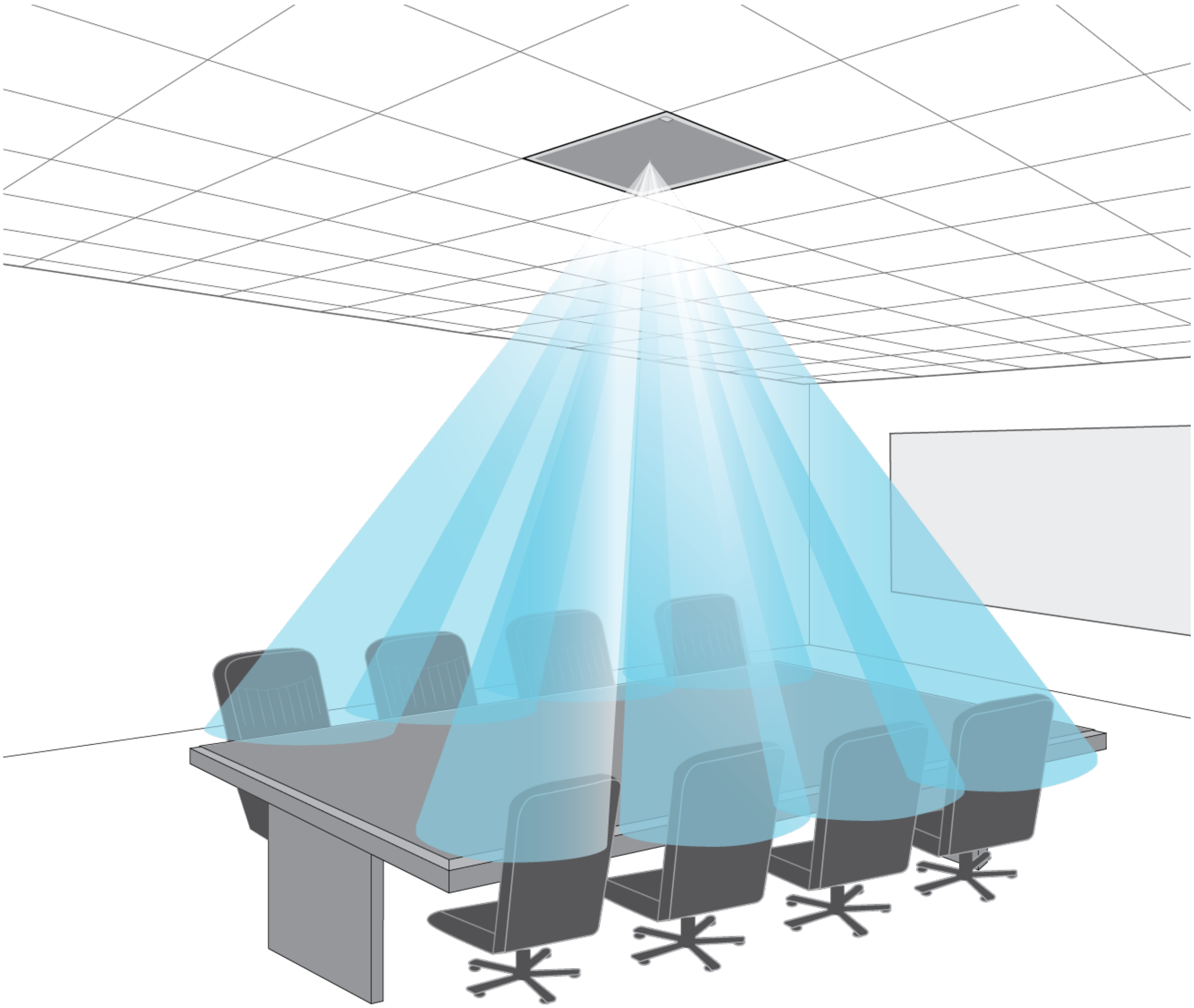
SHURE®

MXA910 -- Ceiling Array Microphone

Overview

General Description

The Microflex®Advance™ Ceiling Array is a premium networked array microphone for AV conferencing environments, including boardrooms, huddle rooms, and multi-purpose spaces. Revolutionary technology from the Shure DSP suite includes Steerable Coverage™, with 8 highly directional pickup lobes that capture participant audio from overhead. Control the microphone with Shure Designer software, or a browser-based web application. The microphone integrates seamlessly with Dante™ digital networked audio and third-party preset controllers, including Crestron and AMX, to deliver a high-quality AV conferencing experience that appeals equally to integrators, consultants, and meeting participants.



Features

Configurable Coverage

- Steerable Coverage delivers precise pickup for up to 8 independent lobes
- Shure DSP Suite provides fast-acting automatic mixing, echo reduction, and channel equalization

Software Control

- Shure Designer software provides comprehensive microphone and pattern control
- With Designer, you can also design coverage with online and offline devices, and route audio between Shure devices
- If Designer isn't available, use the browser-based web application to control the microphone

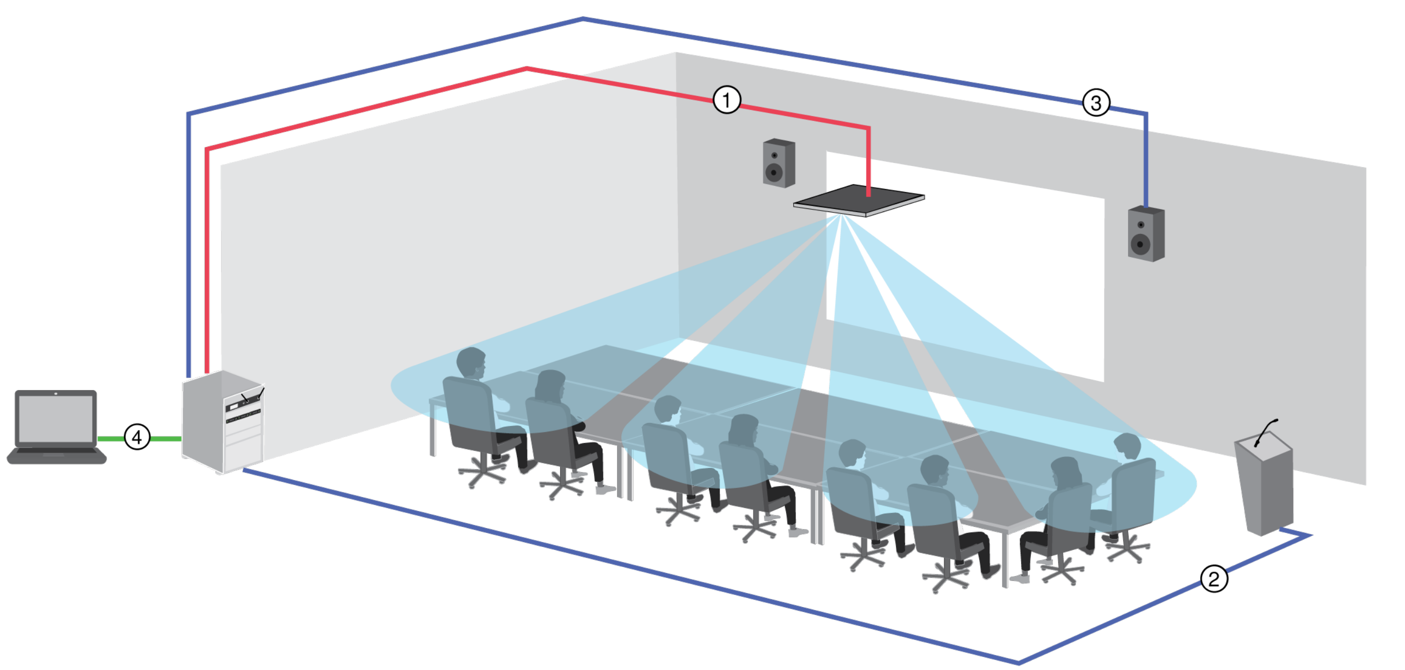
Network Connectivity

- Discrete audio channels for each lobe and an automix channel are delivered over a single network cable
- Dante digital audio coexists safely on the same network as IT and control data, or can be configured to use a dedicated network
- Control strings available for third-party preset controllers including Crestron and AMX

Professional Design

- Sleek industrial design blends with contemporary board rooms and meeting spaces
- Seamless flush-mount with standard ceiling tiles
- Available in white, black, and aluminum finishes (detachable grille can be custom painted)

System Overview



① Dante audio, power, and control

Each array microphone connects to the network over a single network cable, which carries Dante audio, Power over Ethernet (PoE), and control information to adjust coverage, audio levels, and processing.

② Analog audio (microphone to network)

Analog equipment, such as a wireless microphone system or a gooseneck microphone on a podium, connects to the Dante audio network through a Shure Network Interface (model ANI4IN) for a completely networked conferencing system.

③ Far-end audio (network to loudspeakers)

Dante-enabled loudspeakers and amplifiers connect directly to a network switch. Analog loudspeakers and amplifiers connect through a Shure Network Interface (model ANI4OUT), which converts Dante audio channels into analog signals, delivered through 4 discrete XLR or block connector outputs.

④ Device control and Dante audio

Control: A computer connected to the network controls the microphone with Shure Designer software. You can remotely adjust coverage, muting, LED behavior, lobe settings, gain, and network settings.

Audio: Route audio with Dante™ Controller or Shure Designer software. Dante Virtual Soundcard enables audio monitoring and recording directly on the computer.

EXHIBIT J

SHURE SOUND EXTRAORDINARY

MENU

Shure Expands Partnership Program With Leading AV Hardware and Software Providers

FEBRUARY 7, 2017

EPPINGEN, GERMANY, February 7, 2017—Shure Incorporated has announced a number of additions to its partnership program, which provide an expanded level of integration between Shure wired and wireless audio systems and other leading AV hardware and software. Shure now has formed partnerships with Cisco, Crestron, Polycom, Biamp, QSC, Symetrix, Yamaha, Audinate, Chief and others.

The partnership program ranges from information for system integrators, such as configuration and setup guides that ensure optimum performance, to embedded plug-ins that provide native control and audio integration. The goal is to communicate that Shure audio products like Microflex® Advance™ and Microflex Wireless have been tested and are compatible with popular downstream equipment. This reduces setup and configuration time for system integrators and administrators and streamlines the workflow involved in using the completed system.

"It's not just about how well products work; it's about how well products work together," said Chad Wiggins, Senior Category Director for Networked Systems at Shure. "The goal of our partnership program is to enhance the 'Five Cs' -- connectivity, control, customization, confidence, and convenience – for our customers. Our success in the marketplace depends more than ever on how easy it is to use Shure products with other brands and other types of products. That's why it's critical that we continue to form partnerships with other significant companies in the AV industry."

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Shure and QSC have co-developed a control plugin for their Microflex Wireless microphone series. In addition, specific microphones in the Shure catalog, including the Microflex Wireless series, can pass audio to the Q-SYS Platform via AES67, all without additional Dante I/O card hardware.

Microflex Wireless

Microphone Solutions for

Description: Microflex® Wireless provides elegant solutions for managing vivid, lifelike sound in AV conferencing environments. Its audio integrates with Q-SYS either through AES67 (without additional hardware) or through Q-SYS Dante I/O card. Q-SYS Designer software also has a built-in control and monitoring plugin available for the Shure Microflex Wireless System. Includes RF Signal status, Level status, Mute and Identify functionality for each microphone.

EXHIBIT L

audiobiz

QSC and Shure to offer integration between Shure Microflex networked microphones and entire Q-SYS Platform (/latest-news/2017/1/11/qsc-and-shure-to-offer-integration-between-shure-microflex-networked-microphones-and-entire-q-sys-platform)

Travis Brown (/latest-news?author=586ff2d13e00be70aef97e2e) · January 11, 2017 (/latest-news/2017/1/11/qsc-and-shure-to-offer-integration-between-shure-microflex-networked-microphones-and-entire-q-sys-platform)

Partnership provides native control and audio integration for best-in-class conference room microphones and AV solutions

Costa Mesa, Calif. (January 9, 2017) QSC, LLC and Shure Incorporated are proud to announce an expanded level of integration between Shure Microflex® Advance™ and Microflex® Wireless microphones with the entire Q-SYS™ Platform. The partnership includes the release of new control plug-ins for the Shure MXA910 Ceiling Array Microphone and Microflex Wireless microphone systems. The latest Q-SYS Designer Software v5.3 update enables a multitude of audio connectivity options including audio integration via Dante, analog audio as well as AES67. Simple setup and configuration is assured with the addition of a detailed quick start guide to integrate audio and control between the Shure and QSC systems.

The Shure MXA910 Control plug-in, co-developed by QSC and Shure, allows a myriad of different audio control, preset recall, and monitoring functions on the MXA910 from the Q-SYS platform using Q-SYS peripherals and touch screen controllers. Because the MXA910 control plug-in is decoupled from the audio integration method in Q-SYS, it lets the integrator use the plug-in for *control* while being able to choose between different *audio* transport methods, whether that be via analog audio using the Shure ANI series, the Q-SYS Dante Bridging card, or the newly-introduced AES67 software support on the Q-SYS Core processor series. By using AES67 as the audio integration method, every Q-SYS Core processor in the platform can be easily integrated with the MXA910 without any additional hardware bridging devices or software licenses. This includes the class-leading Q-SYS Core 110f, offering the industry's most cost effective pairing of DSP, AV Bridging, and Control with its 16 channels of AEC, which can accommodate up to two MXA910s in a single rack space over a single network connection.

The setup guide, also co-developed by QSC and Shure, provides step-by-step instructions on how to integrate the MXA910 with Q-SYS using AES67 for networked audio streaming and the built-in plug-in for control and monitoring of the MXA910 from Q-SYS.

"Integration at the software layer between Q-SYS and the Shure Microflex networked microphones provides integrators with the ability to offer truly unified, AV solutions to their end users for projects of any scale, including those leveraging the new Q-SYS AV-to-USB Bridging solution for conference room camera connectivity to soft-codec applications," explained Martin Barbour, Product Manager for Installed Systems at QSC. "By decoupling control integration from the audio transport mechanism, we offer the integrator the ability to choose the most appropriate audio transport method for their application while ensuring best-in-class performance from microphone through to loudspeaker, including all processing and amplification in between."

"We are tremendously excited to expand our partnership with QSC and to continue improving the overall experience for our shared customers," proclaimed Chad Wiggins, Senior Category Director of Networked Systems Products at Shure. "Offering control plug-ins in Q-SYS Designer Software for the Shure MXA910 Ceiling Array Microphone is a natural extension to the tools already available for Microflex Wireless Microphone Systems. In addition, the setup guide we co-developed provides a valuable resource for system designers considering the technical details of integrating the MXA910 with the Q-SYS platform using AES67. These are great examples of the commitment to improving user workflow and interoperability our two companies share."

Furthermore, because Q-SYS is the only software-based audio, video, and control Linux realtime operating system (RTOS) platform, it will enable QSC and Shure developers to expand the library of control plug-ins to other Shure products and allow integrators to incorporate them into future designs with a simple software update.

The Shure MXA Control Plug-in and setup guide will be available with the release of Q-SYS Designer Software v5.3 in early January 2017.

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EXHIBIT M

Press Releases

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Dec 12, 2016

Biamp Systems and Shure Announce Tesira®-Microflex® Compatibility

BEAVERTON, Oregon and NILES, Illinois — Biamp Systems, a leading provider of innovative, networked media systems and Shure Incorporated, a leading manufacturer of networked microphones, today announced integrated compatibility between Biamp Tesira® audio processors and software and Shure Microflex® Advance™ array microphones with Steerable Coverage™. With the release of Biamp's new Tesira software and hardware at ISE in February 2017, it will be possible to interact with the Dante-enabled Shure MXA910 ceiling array microphone and control signal levels within the Tesira software. This will enable system integrators to deliver flexible, fully-digital audio solutions that meet the complex needs of their clients while reducing installation and setup time.

"We're excited to come together with an industry leader like Shure in an effort to streamline the integration of our products," shared Graeme Harrison, executive vice president of marketing for Biamp Systems. "Both companies value customer feedback and leverage it in future product development. Adding Shure microphone-specific software blocks to Tesira's cutting-edge software made sense; it allows system designers to easily incorporate the power of Shure mics with the power of Tesira. Other developments in this launch will bring this capability to the whole range of Tesira processors, and we will add additional functionality in future releases."

"Interoperability between the MXA910 ceiling array microphone and Tesira processors will make it easier for system integrators to take advantage of its class-leading voice pickup and steerable coverage in a wide assortment of meeting room applications," said Chad Wiggins, senior director for networked systems at Shure. "Together, they deliver a more powerful yet more streamlined solution, with centralized control, simpler installation, and fewer components."

Tesira's software is unique in that it enables system designers to build complete AV solutions using features like its intuitive drag-and-drop interface for a variety of software blocks. The Tesira software enables designers to plan a completely integrated AV solution, including yet-to-be-built future phases.

More information about Biamp and Shure is available at www.biamp.com and www.shure.com.

EXHIBIT N

Using TesiraFORTÉ DAN with Shure MXA310 and MXA910

The purpose of this article is to provide a starting point to aid in the successful deployment of the TesiraFORTÉ DAN with Shure MXA310 and/or MXA910 microphone arrays. Specific understanding of the Shure MXA products is best gleaned from documentation and training provided by Shure. Links to these resources can be found later in this article.

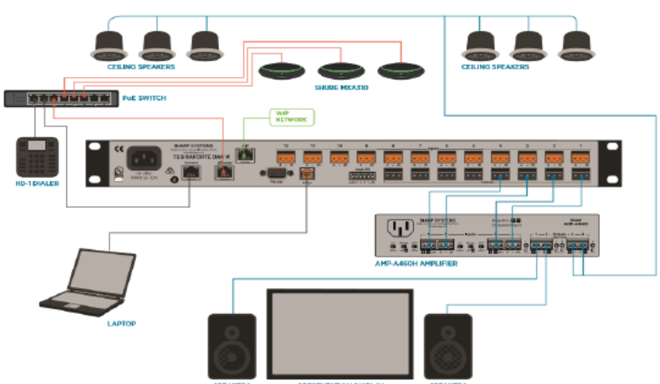
TesiraFORTÉ DAN

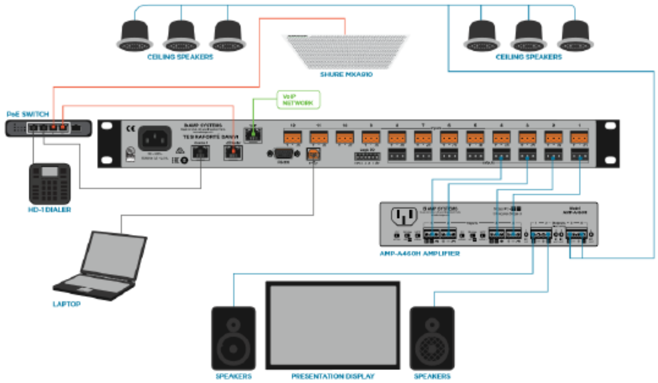
Interoperability

The TesiraFORTÉ DAN product family uses the same TesiraFORTÉ base platform we know and love and adds Dante audio networking. This offers streamlined interoperability with Shure MXA and MXW products as well as Dante products from other manufacturers. Each TesiraFORTÉ DAN is capable of 32 channels in and 32 channels out via the Dante network port. If you are working with an AEC capable TesiraFORTÉ DAN, then you now have up to 12 channels of AEC processing available for Dante microphone sources. This means that a single TesiraFORTÉ DAN can provide AEC processing for up to (3) MXA310 (4 channels each) or a single MXA910 (8 channels each).

***Please note that the TesiraFORTÉ DAN VT4 only has 4 channels of AEC processing available and scale your system design accordingly*.**

Now, we'll borrow some imagery from our System Design Guides to help illustrate these examples:





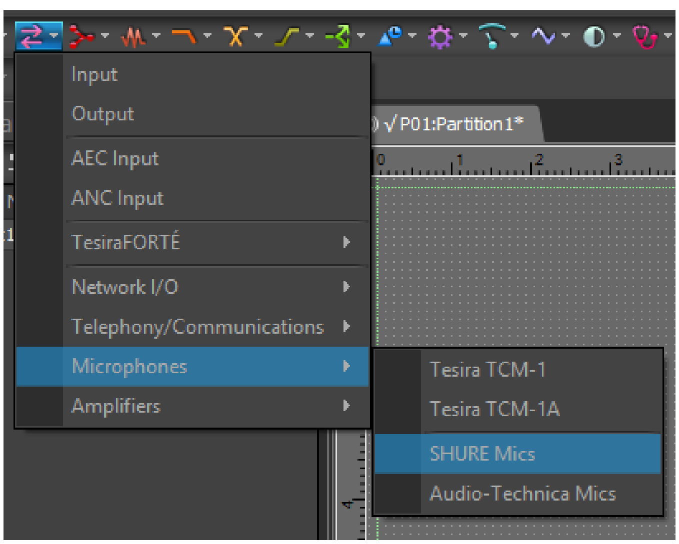
Biamp_System_Design_Guide_Boardroom_TesiraFORTE_DAN_MXA310_EN-US.pdf

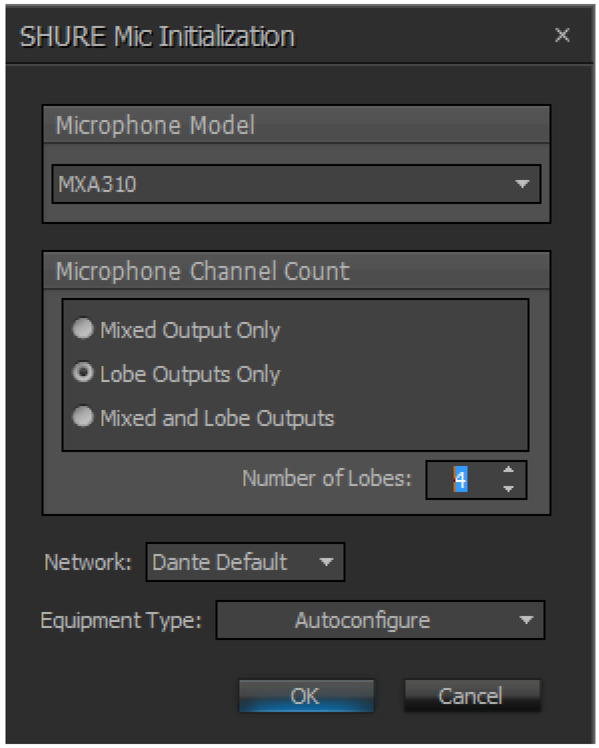
Biamp_System_Design_Guide_Boardroom_TesiraFORTE_DANMXA910_EN-US.pdf

Entire System Design Guide suite.

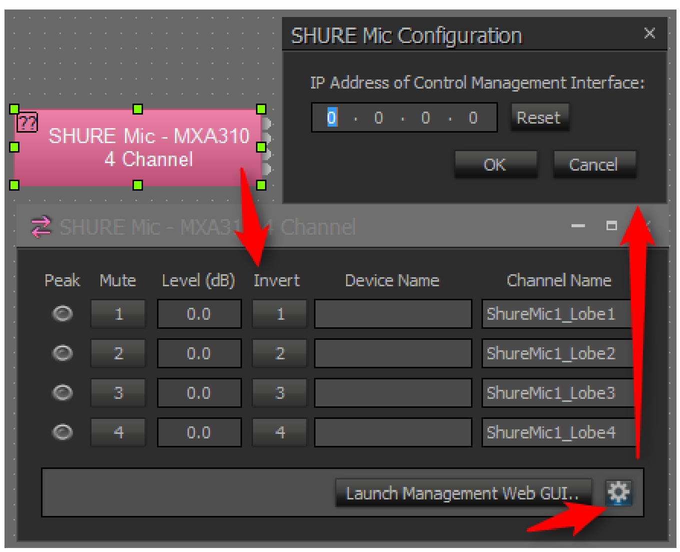
Tesira Software

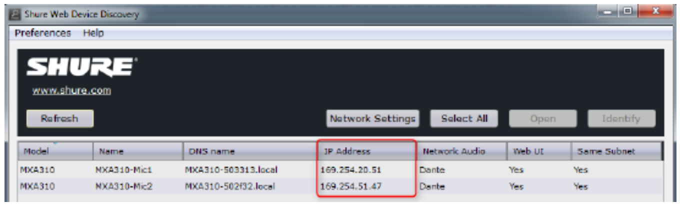
When designing a system file in Tesira software, there are now custom MXA310 and MXA910 blocks located under the "SHURE Mic" option. This can be found in the "Microphones" segment under I/O Blocks within the Object Bar. Once selected, you'll be prompted to choose the desired Microphone Model and Channel Count. The channel or lobe count will need to match the number of lobes expected from the source microphone array. It has been observed that using four individual lobe outputs with Biamp per channel AEC processing performs better than the mixed output option. However, each room and system is unique, so please select the appropriate initialization state.



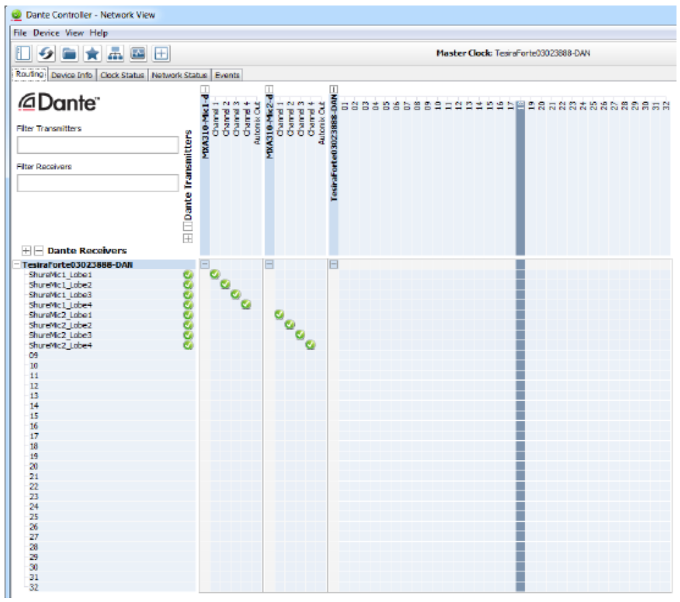


Now that the appropriate input block is created, add the corresponding Control IP Address of the respective MXA mic array in the SHURE Mic Configuration menu. Though not required, this will allow quick access to the Management Web GUI for this specific set of inputs. If the MXA mic array IP address has not already been documented, the Shure Web Device Discovery tool can be used to discover and adjust this information and as needed.





Once the Biamp configuration is sent to the Tesira, available Dante channels will populate within Dante Controller for proper routing.



Dante Hostname & IP Configuration

Dante devices obtain IP addresses automatically by default - so there should be no need to specify static IP addresses unless it is a specific requirement for your network.

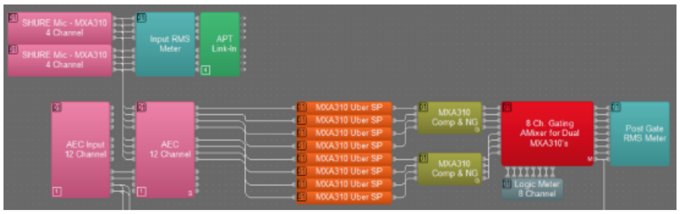
- You can configure static IP addresses and hostnames for the FORTE DAN Ethernet port using Tesira software. Note that these edits must be done with the Tesira in an unconfigured state (no system file loaded; Device ID = 0). In **Device Maintenance > Network Settings** choose the **DAN-1 (Slot x)** tab.
- If your network has a DHCP server, Dante devices will receive their IP configuration using the standard DHCP protocol.
- On a network without DHCP, a Dante-enabled device will automatically assign itself an address using ‘Bonjour’ Zero Config auto addressing protocol by Apple. Devices will automatically assign themselves an address in the range 169.254.*.* (172.31.*.* for the secondary / redundant network, if present).

DAN-1 MAC addresses are visible within **Device Maintenance > Network Settings** under the **DAN-1 (Slot x)** tab, choose the **Interface Status...** button.

MXA LED Control & Example Files

Below are some example files, images and downloadable resources. ***These example files include examples of how to control Mute state and LED's of the MXA310 & MXA910 from Tesira.***

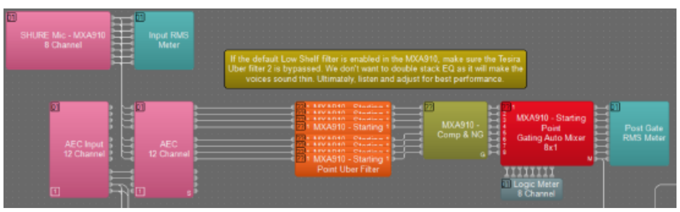
Dual MXA310 System:



File download: Dual_MXA310_Example_file_2017-2-3.tmf

File download: Dual_MXA310_Example_file_2017-2-3_Alt_Mute_Logic.tmf

Single MXA910 System:

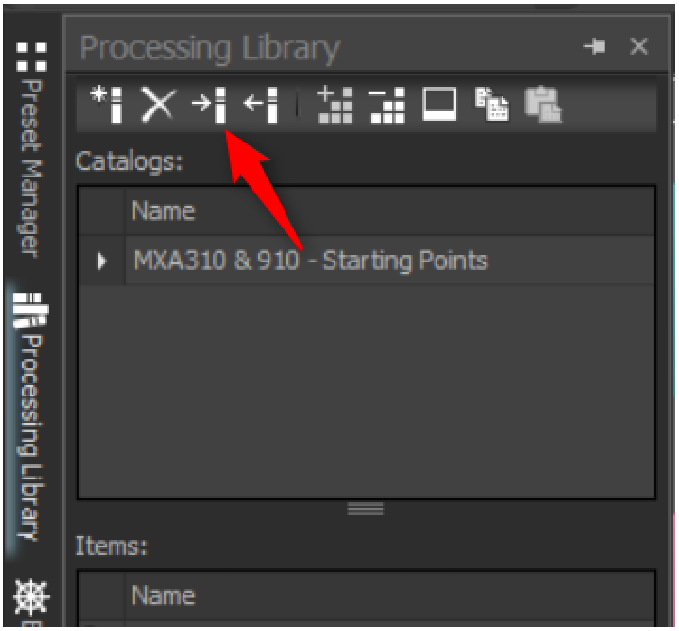


File download: Single_MXA910_Example_file_2017-8-4.tmf

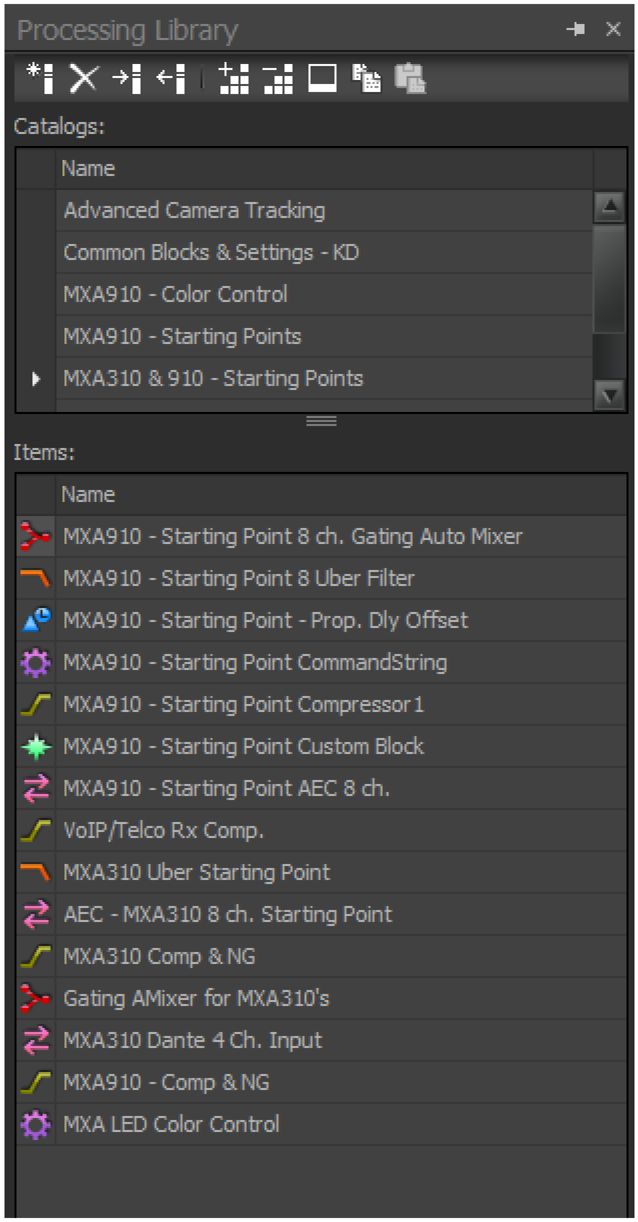
Processing Library:

File download: MXA910_-_Starting_Points_Catalog_v03.tlf

The Processing Library is a little known tool within Tesira software that allows users to create catalogs of their favorite blocks. These catalogs can be exported and shared with other Tesira users. The following image shows the icon used to import the library that was just downloaded.

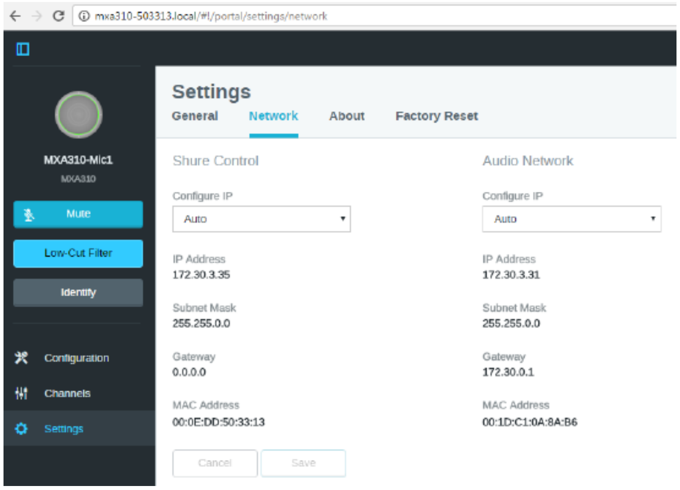


Now, when the Processing Library is opened you will see all of the items that comprise the selected catalog. This catalog contains all the blocks that were used to build the example files above. These items can be added to the current system file simply by dragging and dropping them into the file.



Tips & Tricks:

- It is a good idea to plan out the IP scheme for each system ahead of time.
    - Each Shure MXA device requires two IP addresses, one for control and one for Dante.

- 

- The TesiraFORTÉ DAN will also require two IP addresses, one for control and one for Dante.
- If these addresses are statically set, they will remain the same.
- If these addresses are set to DHCP and drop to link-local (169.254.x.x), the microphones may hop to different IP addresses with each reboot. This would break control and auto-launch functions that were configured in Tesira.
- If there is a DHCP server, it may be best to reserve the necessary IP addresses for the respective devices.

- It is also helpful to strategically name and document each Dante endpoint as this will make routing flows in Dante Controller much more intuitive.

Additional resources

Shure has provided the following documentation and resources for the MXA310:

- Shure MXA310 User Guide
- Shure article on Dante Networks & IGMP Snooping
- Shure Configuration Video
- Shure MXA310 Mounting Hole
- Shure Routing Dante Audio
- Shure MXA310 Interactive Software Demo
- Shure Microflex Advance Training - Video Suite

Further reading

- Using the Shure MXA910 microphone array with Tesira
- Configuring Audio-Technica Dante microphones
- Dante
- Gain Structure
- Microphone Placement

- Gain Sharing vs. Gating Automixers

EXHIBIT O

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MENU

Using multiple MXA910 or MXA310 microphone arrays in a single room.

FAQ #4982 Updated September 07, 2017

Question:

Can I use more than one MXA910 ceiling array or MXA310 table arrays in a room? How do they connect together?

Answer:

Yes. Just like any other microphone, you may install multiples to cover a room.

The audio output from multiple ceiling arrays (or table arrays) can be combined with a mixer or external DSP (i.e. SCM820, or QSC Qsys, or Biamp). Multiple arrays cannot directly share DSP resources with each other.

The microphones cannot be daisy-chained together, but by installing a small network switch with PoE under the table or in a ceiling, multiple array microphones can be locally connected and then a single cable run from the switch back to a central location.

Note that each microphone must be configured independently. At this time, the embedded software in the device does not allow for multiple devices to be configured from a single interface.

Shure Designer software can be used allows multiple "virtual" MXA910 Ceiling Array Microphones to be configured in one tool. Arrange pickup lobes over a room diagram for precise coverage; import saved settings to each MXA910 on site.

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By: */s/ Sourabh Mishra*